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Mining Research Laboratories
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Canada/NB MDA Project on Mine-shaft Rope Testing; testing of $\frac{7}{8}$ in., 1×90, L.C., H. R., (our ropes #13 & #14)

L.B. Geller, D. Poffenroth, J.E. Udd, and D. Hutchinson

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MICROMEDIA

55 pp

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CANADA/NB MDA PROJECT ON MINE-SHAFT ROPE TESTING; TESTING OF $\frac{7}{8}$ in., 1×90, L.C., H. R. (OUR ROPES #13 & #14)

by

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ABSTRACT

In this report the authors analyse the test-results obtained non-destructively on two $\frac{7}{8}$ in. diameter, 1×90, Locked-coil (L.C.), hoist-ropes (H.R.). The ropes were only examined in-situ, as part of CANMET's project to comparatively evaluate the performance of a range of EM wire-rope testers. This is the first time that a project of this magnitude and diversity has been undertaken.

The ropes were tested with the Canadian Magnograph and Rotescograph, and with the American LMA-250 instruments. For ropes #13 and #14, respectively, the maximum estimated strength-loss (LBS) was reported at 9.0% and 7.0% by the Rotescograph operator, and at 5.0% and 7.5% by the Magnograph operator. The operator of the American instrument did not submit LBS estimates.

Within the context of CANMET's present project it was intended to only test ropes that were just about ready to be discarded — i.e., that were in a bad, or very bad, condition — in order that the ropes might be tested both in-situ, and soon afterwards, also on the shop-floor reel-to-reel. In this context the condition of our ropes #13 and #14 was too good. However, even though in the present case we only obtained in-situ test results on relatively new ropes, the results are of special interest because total rope-lengths could only be examined with two instrument set-ups. The results obtained are analysed with special reference to such important parameters as their repeatability, comparability, and levels of accuracy.

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Keywords: New Brunswick; Mineral Development Agreement; Wire-ropes; Non-destructive-testing; Electro-magnetic instruments; Hoist-ropes; Locked-coil ropes

EEM CANDA/NB SUR L'ESSAI DE CÂBLE DE PUITS DE MINE; ESSAI DE CL À TC, 1×90, DE 7/8 PO (NOS CÂBLES NO 13 ET 14)

par

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RÉSUMÉ

Dans le présent rapport, les auteurs analysent les résultats d'essais non destructifs menés sur deux câbles de levage (CL) à toron clos (TC), 1×90, de 7/8 po de diamètre. Les câbles n'ont été examinés que sur place dans le cadre du projet de CANMET visant à évaluer comparativement les rendements de divers appareils ÉM d'essai des câbles métalliques. C'est la première fois qu'un projet de cette ampleur et de cette diversité est entrepris.

Les câbles ont été vérifiés avec le Magnograph et le Rotescograph canadiens, et avec l'instrument LMA-250 américain. Pour les câbles no 13 et 14, les pertes de résistance (LBS) maximales respectives ont été estimées à 9.0% et 7.0% par l'opérateur du Rotescograph, et à 5.0% et 7.5% par l'opérateur du Magnograph. L'opérateur de l'instrument américain n'a soumis aucune estimation de LBS.

Dans le contexte du présent projet de CANMET, le but était seulement de tester des câbles sur le point d'être mis au rebut, c'est-à-dire dans un mauvais ou très mauvais état, de manière à pouvoir les tester tant sur place que peu après, de même que sur le plancher de l'atelier, sur toute leur longueur. Dans ce contexte, létat de nos câbles no 13 et 14 était trop bon. Cependant, même si nous n'avons dans le présent cas obtenu que des résultats déssai in-situ sur des câbles relativement neufs, les résultats présentent un intérêt particulier parce que les câbles n'ont pu être examinés sur toute leur longueur qu'avec deux appareillages. Les résultats obtenus sont analysés, notamment en ce qui a trait à des paramètres aussi importants que leur répétitivité, leur comparativité, et leurs niveaux d'exactitude.

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Mots clés: Nouveau-Brunswick; Entente sur l'exploitation des minéraux; câbles métalliques; essai non destructif; instruments électromagnétiques; câbles de levage, câbles à toron clos

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BACKGROUND

The results described in this report constitute an integral part of the contracted phase of CANMET's project, undertaken in 1986 in response to requests by both the mining industry and the mine regulatory authorities. The basic project objectives specified that the continuing rope failures, or near failures — occurring despite mandatory wire-rope examinations with electro-magnetic (EM) instruments at regular intervals — be examined, documented, analysed, and the reasons for these occurrences clarified. This is the first time a project of this scope and depth has been undertaken, anywhere.

CANMET's work included both in-house and contracted work phases. The in-house phase resulted in a range of conclusions and recommendations, reported elsewhere (references 1 through 6). We are now in the process of reporting the results obtained during the contracted project-phase, which included an extensive series of both in-situ and shop-floor tests. The first thirteen reports to describe this project phase were prepared in the period February, 1990, through March, 1991 (references 7 through 19). More are to follow.

ROPE DETAILS

Of the four hoist-ropes in service in shaft #1 of Mineraux Noranda's Lac Matagami mine, Québec, two (mine ropes #2 and #3) were tested on 1988 03 14* and 1988 03 15 in-situ, as part of CANMET's project. These two, designated as our ropes #13 and #14, are the subject of this report. These were $\frac{7}{8}$ diameter, 1 × 90, L.C. ropes, with reel numbers 644660-3 (our rope #13) and 543390-2 (our rope #14). They were installed on 1987 11 28. They were still in use at the time of completion of Phase I of CANMET's project in question. Their corresponding balance ropes were of $1\frac{7}{16}$ in., 34 × 7, construction.

We do not, unfortunately, have any further details about the hoist-ropes' operational history, other than the relevant NDT results. These are listed hereunder.

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*: dates are given in this order: year, month, day

IN-SITU TEST RESULTS — AS REPORTED AND REVIEWED

The Magnograph Data

Prior to our own tests, in-situ tests were performed, under standard operating conditions, with a Magnograph instrument on: 1988 05 25 (report #88-256B for rope #13 and #88-256C for rope #14), and on 1988 09 21 (report #88-463L for rope #13 and #88-463M for rope #14). Our own tests followed on 1989 03 14 (report #89-169B for rope #13 and #89-169A for rope #14).

For rope #13 the maximum loss-of-metallic-area (LMA_{max}) values in these three reports were, respectively: 1.5%, 11.0%, and 5.0%. For rope #14 the respective values were: 2.0%, 10.5%, and 7.5%. Negligible to light corrosion was reported along the entire tested rope length.

Loss-of-breaking-strength (LBS) was not reported. However, on inquiring, we were told that the estimated $\%LBS_{max}$ could be set equal to the reported $\%LMA_{max}$ figures. We also questioned why the reported $\%LMA_{max}$ values of the penultimate test exceeded those of the ultimate one. We were told that this was due to an error in setting — during the 1988 09 21 tests — the Magnograph's gain-setting at a dial value of 960 instead of at 745, as should have been the case.

For rope #13 we reproduce the operator's strip-charts in Fig. 1, and for rope #14, in Fig. 2. We added to these charts our own chart-alignments (Fig. $1c_2$ and Fig. $2c_2$), as well as our own marking of: (1) the 100% reference levels, (2) the relevant sensitivity scales (%LMA per major chart-division), (3) the %LMA chart-readings at the most important rope locations, and (4) the characteristic 'fingerprints' — i.e., rope defects 'X', 'Y', and 'Z'. It is quite remarkable how consistently, and clearly, these 'fingerprints' can be detected on the various strip-charts, even though the latter were obtained at different times, and on different, be it 'companion', ropes.

We list respective %LMA chart-readings in Table 1. Moreover, in view of the influence of the instrument calibration procedures upon the test-results, we also record relevant information about matters such as: (a) the rope-end at which calibration was effected, (b) the rope-end at which 0.0% LMA was found to be, and (c) the %LMA difference between the two rope-ends. In addition we list both the reported %LMA data, and our own corresponding chart-readings. In case of rope #14 the differences are excessive. As mentioned earlier, the operator referred to mistaken gain-settings as the cause of some of the problems. In our opinion this mistake was further compounded by problems with proper alignment of the two chart-segments (i.e., of the West- and

East-skip rope-ends) — due to the absence of temporary 'markers', and to excessively slow chart-speeds. White paint-marks were reported to exist along several yards in the Eastern-skip rope section. However, they seemed to be of little help in facilitating proper chart-splicing.

The Rotescograph Data

In-situ testing with a Rotescograph instrument was undertaken on 1989 03 15. For rope #13 we reproduce the operator's strip-charts — as submitted to us — in Fig. 3, and for rope #14, in Fig. 4. As will be noted, this operator, mistakenly, treated the West-skip and East-skip chart-segments as if they were two separate and independent entities, with no need to be spliced together, and with two separate 100% reference levels. The reported LMA_{max} values were 3.0% for rope #13 (West) and 4.5% for rope #13 (East), as well as 3.5% for rope #14 (West) and 3.5% for rope #14 (East). The operator marked these values on the respective strip-charts (Figures 3 and 4). The 100% reference levels were not marked on the operator's charts. Minor corrosion was reported along the entire rope-length tested.

To obtain our own chart-readings we aligned and marked the given strip-charts ourselves. We reproduce these charts in Figures 5 and 6, for ropes #13 and #14, respectively.

All %LMA chart-readings are listed in Table 1. The differences between the reported and reviewed data are excessive in case of rope #14. In view of the aforementiond error of treating the two chart-segments as if they were two separate entities, this is to be expected. The relative congruence of the 'reported' and 'reviewed' %LMA data for rope #13 is, on the other hand, merely coincidental.

In view of the influence of the instrument calibration procedures upon the test-results, we also recorded in Table 1 relevant information about matters such as: (a) the rope-end at which calibration was effected, (b) the rope-end at which 0.0% LMA was found to be, and (c) the %LMA difference between the two rope-ends.

Wherever we were unable to reproduce the strip-charts in a single length, we provided match-marks (such as ref. 'A'; ref. 'B'; etc.) on the individual chart-segments.

The operator also submitted LBS estimates. These were obtained by doubling the corresponding %LMA chart-readings.

The LMA-250 Data

In-situ testing with an LMA-250 instrument was undertaken on 1989 03 15. For rope #13 we reproduce the operator's strip-charts — as submitted to us, plus our own marking of the 100% reference levels and of the characteristic rope defects 'X', 'Y', and 'Z' — in Fig. 7, and for rope #14, in Fig. 8. This operator undertook: (a) six separate test-runs on rope #13 (namely runs #1, 2, and 3, on the West-skip rope-end, and #6, 7, and 8 on the East-skip rope-end) and (b) another six on rope #14 (namely runs #4 and 5 on the West-skip rope-end, and #9, 10, 11, and 12 on the East-skip rope-end). The operator's reported %LMA chart-readings are based on a combined chart that is spliced together from runs #3 and #8 for rope #13 (Fig. 7), and from runs #5 and #11 for rope #14 (Fig. 8). The strip-charts of the test-runs not used for for these combined charts are reproduced — as submitted to us, plus our own marking (where appropriate) of the 100% reference levels and of chart-defects 'X', 'Y', and 'Z': (a) in Fig. 9 for rope #13 (run numbers 1, 2, 6, and 7, and (b) in Fig. 10 for rope #14 (run numbers 4, 9, 10, and 12).

In Fig. 11 we reproduce two additional charts obtained by the operator on rope #13, West-skip rope-end, with the Magnograph's Gould-222 recorder, instead of with the LMA-250 instrument's regular recorder. These do not contain any additional information of note.

Finally, we reproduce in Fig. 12 another combined strip-chart of rope #13. We ourselves prepared this chart by splicing together, and marking, the operator's test runs #2 and #6. In Fig. 13 we reproduce a similar additional chart which we prepared for rope #14 by splicing together test runs #4 and #12.

All %LMA chart-readings are listed in Table 1. Our own chart-readings agree with the originally reported ones. We also list the %LMA chart-readings at the characteristic rope-defect locations 'X', 'Y', and 'Z'. Moreover, in view of the influence of the instrument calibration procedures upon the test-results, we record relevant information about matters such as: (a) the rope-end at which calibration was effected, (b) the rope-end at which 0.0% LMA was found to be, and (c) the %LMA difference between the two rope-ends.

Wherever we were unable to reproduce the strip-charts in a single length, we provided match-marks (such as ref. 'A'; ref. 'B'; etc.) on the individual chart-segments.

The operator did not report estimated %LBS values. The report did, however, mention: (a) that LMA was due to corrosion, with the entire tested rope length being corroded to a varying degree, and that the greatest losses occurred in a visibly wet

rope-segment relatively close to the East-skip rope-end, (b) that the contoured shapes of the LC wires appeared to have deteriorated, and (c) that there were white paint marks along the East-skip rope-segment, these marks being used when re-setting the instrument for the second test-run, required to complete testing along the entire rope length.

DESTRUCTIVE TESTING

Ropes #13 and #14 were still in use at the time Phase I of CANMET's project on cooperative evaluation of a range of EM testers was concluded. Consequently, no destructive testing was performed.

ANALYSIS OF TEST RESULTS

(1) General Comments

Considering the influence of the instrument calibration-procedures upon the test-results, we included relevant information about these matters in Table 1, such as: (a) the rope-end at which calibration was effected, (b) the rope-end at which 0.0%LMA was found to be, and (c) the %LMA difference between the two rope-ends. It is interesting to note that the actual shape of the presently discussed LMA strip-charts closely resembles the situation chosen for the theoretical examination (Table 5 and Fig. 8 of ref. 17) of the abovenoted influence. Unfortunately, we have no reconfirmable data with which to verify the Magnograph operator's calibration procedures in the present case. However, in order to re-emphasize the major influence of these procedures, we reproduce (see Table 3 and Fig. 14) the aforementioned Table 5 and Fig. 8 of reference 17.

Wherever we were unable to reproduce the strip-charts in a single length, we provided match-marks (such as: ref. 'A'; ref. 'B'; etc.) on the individual chart-segments. Moreover, we added to all charts: (a) the 100% reference levels, (b) the relevant sensitivity scales (%LMA per major chart-division), (c) the 'X', 'Y', and 'Z' rope defect locations and (d) the %LMA chart-readings at the most important rope-locations.

Details of the test set-ups are listed in Table 2.

(2) LF Chart Readings

Broken wires in rope #14 showed up quite consistently on the LF-traces of all the instruments. They were not, however, of major significance. Corrosion, of varying degrees, along the entire rope-lengths was more significant.

(3) LMA Chart Readings

We tabulated both the originally reported %LMA chart-readings, and the reviewed values, in Table 1. In some cases the differences between the two are unacceptably large. In our opinion the main difficulty was caused by the problems some of the operators had with the two test set-ups. Consequently, some faulty chart alignments and splicing resulted. Even in case of correct procedures though, the results would have been better: (a) had the respective EM testers been calibrated, for both test set-ups, along the same rope-length in the overlapping segment, (b) had a temporary 'marker' been placed in the overlapping segment, so that splicing together of the two chart-segments could have been done more easily, and more accurately. It would appear that a major rope-anomaly might, in fact, have been present at the very location where the EM instruments were set up for a second time, making correct chart-alignment and splicing even more difficult without the assistance of a 'marker'.

In case of the Magnograph-tests correct chart-alignment was further complicated by the relatively slow chart-speeds used, i.e., by the excessively crowded sequence of events on these charts.

It should be noted that the need for two test set-ups is not an infrequent occurrence. This procedure is necessary whenever results along the entire rope length cannot be obtained otherwise.

The %LMA chart-readings could best be compared at the characteristic rope defect locations 'X', 'Y', and 'Z'. Most of the 'reviewed' data are in fair agreement with each other. The existing discrepancies are, probably, mostly due to our own difficulties with chart-splicing, due to the absence of temporary 'markers'. It was remarkable how conspicuously, and consistently, these rope-anomalies showed up, even though the tests were obtained with different instruments, different operators, at different times, and not even always on the same ropes (even if the two ropes were 'companion' ones).

The reported Rotescograph data were unacceptable, because the operator failed to combine the West- and East-skip chart-segments. Moreover, the 1989 09 21, penultimate, Magnograph %LMA test-results were, obviously, obtained with a wrong gain-setting. It is disturbing to note that the latter type of mistake seems to happen relatively

frequently, in case of other operators and instruments as well (e.g., note references 8 and 10). Phase II of CANMET's project on EM instrument evaluation attempts to remedy this problem, among others.

The ropes were in a relatively good condition.

(4) Temporary Rope 'Markers'

The need to attach temporary 'markers' to the ropes has been emphasized in several previous reports of this series (e.g., note references 14, 17, and 19). Such a 'marker' should be attached to the rope-end at which testing initiation and instrument calibration occurs. Its distance from some permanent rope fixture, such as the conveyance or counterweight, should be recorded, so that the distance-marks along the strip-chart edges become more meaningful. Moreover, such a temporary 'marker' must also be attached to the overlapping rope-section whenever two instrument set-ups are used, such as was presently the case with our ropes #13 and #14. As noted in our report, the situation was such (e.g., due to the probable presence of an anomaly in the overlapping rope-segment) that it was almost impossible to accurately splice together the two strip-chart segments without the aid of such a 'marker'. The resulting discrepancies in the %LMA chart-readings (Table 1) illustrate the consequences.

To date the usual practice with operators who do attach temporary 'markers', was to tape a sufficiently long and adequately sized 'calibration' wire into the groove between adjacent rope-strands. An example (after Fig. 10 of ref. 17) is reproduced in Fig. 15. Unfortunately, this practice cannot be used with locked-coil ropes, such as our ropes #13 and #14. We, therefore, recommend a different procedure, instead. It is both novel and effective, as well as simple to apply. The process involves the following:

— cut a, say, 1 cm wide strip of a magnetically permeable and flexible foil, possibly one with magnetic shielding properties and preferably one with pressure sensitive tape backing and a release coated liner;

— wind one, or two, layers of this strip around the wire-rope at the appropriate location, having first degreased this spot with, say, a varsol-soaked rag;

— further secure this strip in place by cutting a suitable length of a, say, 3 to 5 cm wide strip of some other pressure-sensitive tape, and by wrapping the latter around the former.

In our case we used a 1 cm wide × 0.254 mm (0.010 in.) thick CO-NETIC AA foil, with magnetic shielding properties, as the 'marker'. It has a double-faced pressure sensitive tape and release coated liner. We wrapped two layers of it around a $\frac{3}{4}$ in.

diameter, 6×19, Seale, IWRC, test-rope. The latter has 0.060 in. diameter outside wires and a total metallic cross-sectional area of 0.26656 in^2. We also secured this 'marker' in place by winding a 4 cm wide mylar packing tape around it. We reproduce a sketch of the foregoing procedure, as well as of the technical details of the CO-NETIC AA foil in question, in Fig. 16.

On passing this 'marker' through a Magnograph, we obtained the characteristic LF trace reproduced in Fig. 17. As illustrated, this is a very substantial perturbation, equalling that which is caused by three broken 0.060 in. diameter neighbouring outside wires in a single strand, with a 1 cm gap between the broken wire ends. From Fig. 17 it is also clear that the added magnetic material is easy to distinguish from other rope anomalies, because it (i.e., the 'marker') shows up in opposite phase to the regular rope defects (i.e., to missing magnetic material).

This characteristic is also helpful in determining the correct sequence of events occurring along the strip-chart, as has been pointed out elsewhere, as an example in reference 7. In the latter case this physical instrument characteristic was used to accurately locate the position of certain artificial rope-defects (with both missing and additive magnetic materials) as shown in Fig. 18. In case of EM rope-testing this characteristic is helpful in determing whether the two rope segments in question were 'rising' or 'descending' — and thus the correct direction in which the chart-segments have to be spliced together.

According to Fig. 16 the manufacturer is able to supply this 'marker' foil in a width (say of 1 cm) most suitable for use under specific operational circumstances. Of course other ferro-magnetic materials with similar properties are equally suitable, such as thin sheets of transformer core-material, as an example.

(5) LBS Estimates

Since we had no reliable information about the rope's original breaking-strength, and were unable to conduct our own destructive testing, we had no way of checking the accuracy of the operators' LBS estimates. It is interesting to note, though, that the maximums ranged from a low of 5.0% to a high of 9.0% for rope #13.

(6) Repeatability and Comparability

It is remarkable how consistently, and clearly, the characteristic 'fingerprints' 'X', 'Y', and 'Z' show up on: (a) the strip-charts of both ropes #13 and #14, and (b) the strip-charts of all three instruments tested. Unfortunately, this repeatability aspect is true only qualitatively; quantitatively the results compare less favourably, due, primarily, to difficulties with proper chart-splicing. In one case mistaken instrument gain-setting was also noted.

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APPENDIX

Tables 1, 2, and 3

as well as Figures 1 through 18, inclusive

Table 1a

In situ test-results for rope #13

Subject	Magnograph		Rotescograph		LMA-250	
	$\alpha^{\dagger}$	$\beta^{\ddagger}$	α	β	α	β
LMA^*_{max}, on						
1988 05 25	1.5%	1.9%				
1988 09 21	11.0%	12.6%				
1989 03 14&15	5.0%	5.6%	4.5%	5.6%	6.6%	6.6%; 6.8%
LMA*, on						
1989 03 14&15,						
at: X_1		2.8%		3.6%		5.0%; 5.4%
X_2		3.0%		3.6%		5.6%; 5.0%
Y_1		4.8%		4.1%	6.0%	6.0%; 6.2%
Y_2	5.0%	5.6%	4.5%	5.3%	6.6%	6.6%; 6.8%
Z_1		4.7%		5.3%	6.0%	6.0%; 6.2%
Z_2		3.5%		4.3%		4.9%; 5.2%
Z_3		1.4%		3.1%		3.9%; 3.9%
LMA diff. betw. rope-ends††	1.0%		1.4%; 1.2%		2.6%; 2.6%	
Tested rope lengths, on:						
1988 05 25	1,143 ft					
1988 09 21	1,158 ft					
1989 03 14&15	1,137 ft		1,173 ft		1,124 ft	

* — chart-readings

† — as reported

‡ — as reviewed

†† — (1) chart-readings off 1989 03 14&15 strip-charts;
(2) in all cases, instrument calibration: (a) at West-skip rope-end for testing of first (approximately 800 ft long) 'West-skip' rope-segment, and (b) some 320 ft from East-skip rope-end, for testing of second (approximately 320 ft long) 'East-skip' rope-segment;
(3) in all cases, 0.0% LMA was located at East-skip rope-end

Table 1b

In situ test-results for rope #14

Subject	Magnograph		Rotescograph		LMA-250	
	$\alpha^{\dagger}$	$\beta^{\ddagger}$	α	β	α	β
LMA^*_{max}, on						
1988 05 25	2.0%	3.8%				
1988 09 21	10.5%	12.8%				
1989 03 14&15	7.5%	10.6%	3.5%	10.7%	10.6%	10.6%; 7.9%
LMA*, on						
1989 03 14&15,						
at: X_1		4.8%		5.7%		5.5%; 3.9%
X_2		7.7%		7.4%		8.0%; 6.6%
Y_1	7.5%	10.4%	3.5%	9.3%	9.5%	9.5%; 6.9%
Z_1		8.7%		7.1%	7.8%	7.8%; 7.9%
Z_2		4.4%		4.0%		3.7%; 4.0%
Z_3		2.8%		3.6%	3.3%	3.3%; 3.3%
LMA diff. betw. rope-ends††	2.9%		2.5%; 3.4%		3.1%; 1.7%	
Tested rope lengths, on:	-					
1988 05 25	1,143 ft					
1988 09 21	1,155 ft					
1989 03 14&15	1,140 ft		1,183 ft		1,122 ft	

* — chart-readings

† — as reported

‡ — as reviewed

†† — (1) chart-readings off 1989 03 14&15 strip-charts;
(2) in all cases, instrument calibration: (a) at West-skip rope-end for testing of first (approximately 800 ft long) 'West-skip' rope-segment, and (b) some 320 ft from East-skip rope-end, for testing of second (approximately 320 ft long) 'East-skip' rope-segment;
(3) in all cases, 0.0% LMA was located at East-skip rope-end

Table 2

Details of in-situ testing of the two $\frac{5}{8}$ in., 1×90, L.C., H.R.

Item No.	Test Instr.	Test No.	Test date	Rope No.	Instr. operator*	Test chart: Fig. #
1	Magnograph	#88-256B	1988 05 25	13	(2)	1a
2	Magnograph	#88-463L	1988 09 21	13	(2)	1b
3	Magnograph	#89-169B	1989 03 14	13	(2)	$1c_2$
4	Rotescograph	ME-001RPN	1989 03 15	13	(6)	5a; 6a
5	LMA-250	—	1989 03 15	13	(5)	7; 12
6	Magnograph	#88-256C	1988 05 25	14	(2)	2a
7	Magnograph	#88-463M	1988 09 21	14	(2)	2b
8	Magnograph	#89-169A	1989 03 14	14	(2)	$2c_2$
9	Rotescograph	ME-001RPN	1989 03 15	14	(6)	5b; 6b
10	LMA-250	—	1989 03 15	14	(5)	8; 13

*: (2) service company
(5) government organisation
(6) mining company

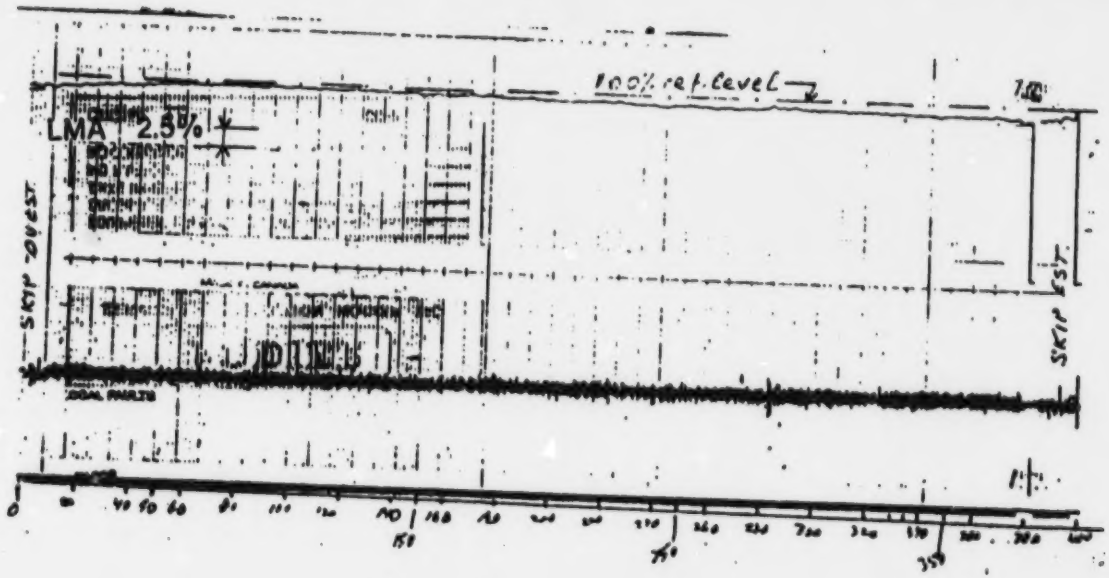
Table 3 (see also Fig. 14)

Comparison of %LMA and $\%LMA_{total}$ test-results

Results at point	Results at stage	With calibr. at	LMA readings*	LMA_{total} values †
'A'	1	'A'	11.1%	18.2%
		'C'	10.0%	18.2%
	2	'A'	17.6%	22.7%
		'C'	15.0%	22.7%
	3	'A'	12.5%	27.3%
		'C'	11.1%	27.3%
'B'	1	'A'	22.2%	27.3%
		'C'	20.0%	27.3%
	2	'A'	23.5%	27.3%
		'C'	20.0%	27.3%
	3	'A'	25.0%	36.4%
		'C'	22.2%	36.4%
'C'	1	'A'	0.0%	9.09%
		'C'	0.0%	9.09%
	2	'A'	0.0%	9.09%
		'C'	0.0%	9.09%
	3	'A'	0.0%	18.2%
		'C'	0.0%	18.2%

*: per respective strip-charts

†: per respective strip- and calibration-charts



(a) 1988 05 25 test #88-256B; rope length = 381 yards (1,143 ft)

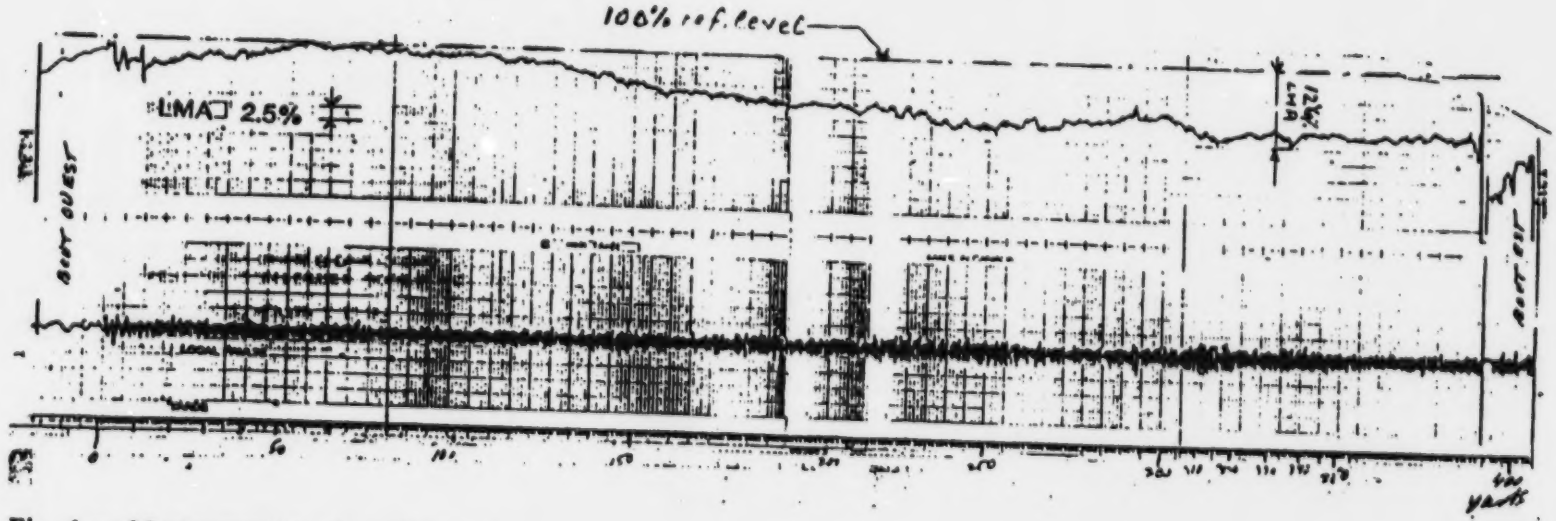
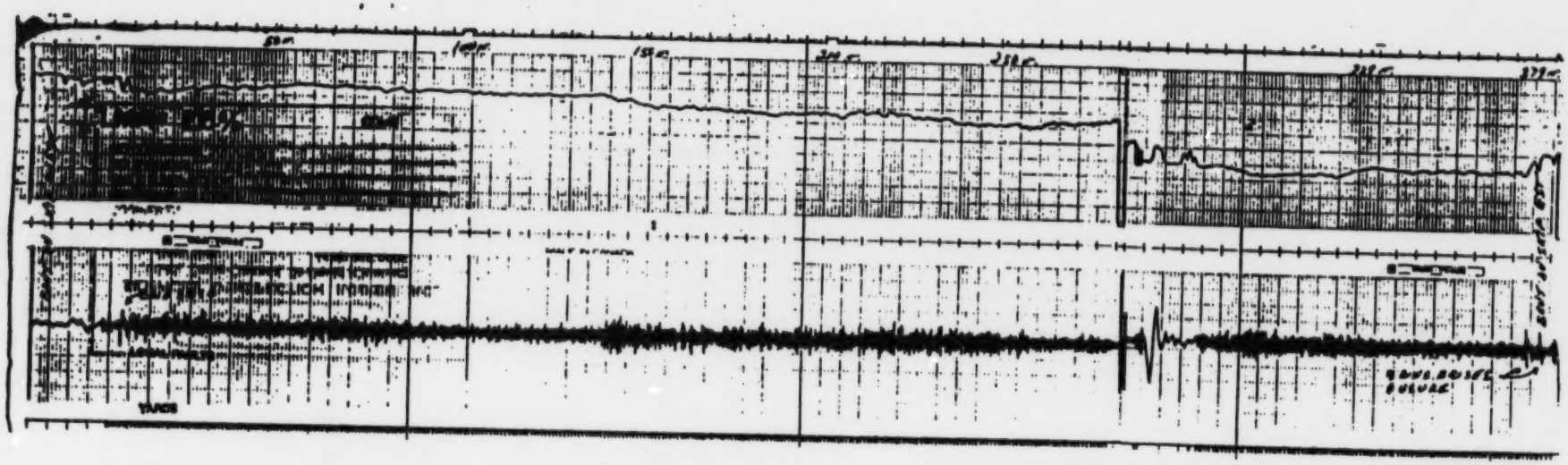


Fig. 1 — Magnograph testing of rope #13

(b) 1988 09 21 test #88-463L; rope length = 386 yards (1,158 ft)



(c$_1$) 1989 03 14 test #89-169B, test #1; rope length = 379 yards (1,137 ft)

Fig. 1 (continued) — Magnograph testing of rope #13

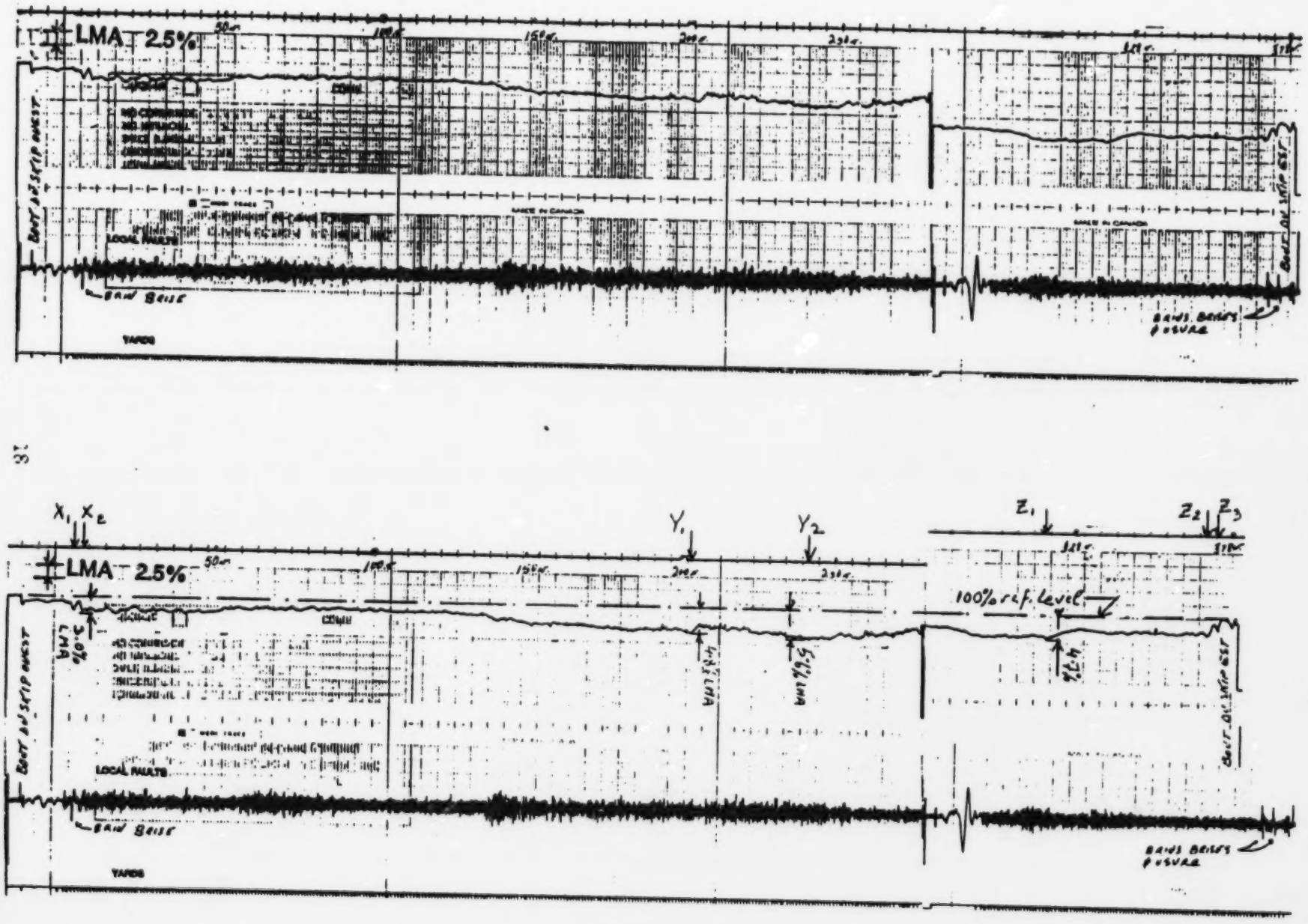
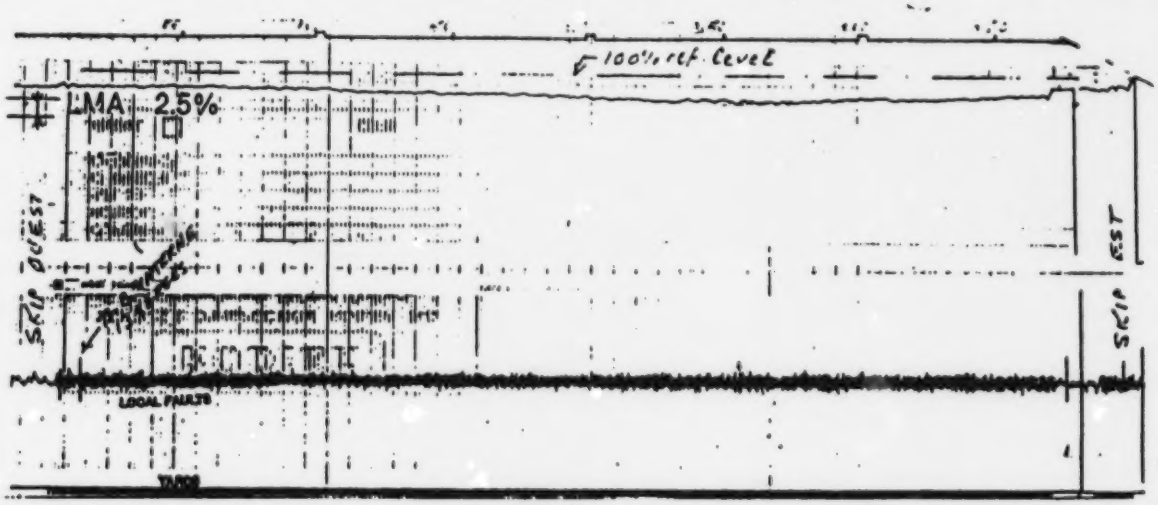
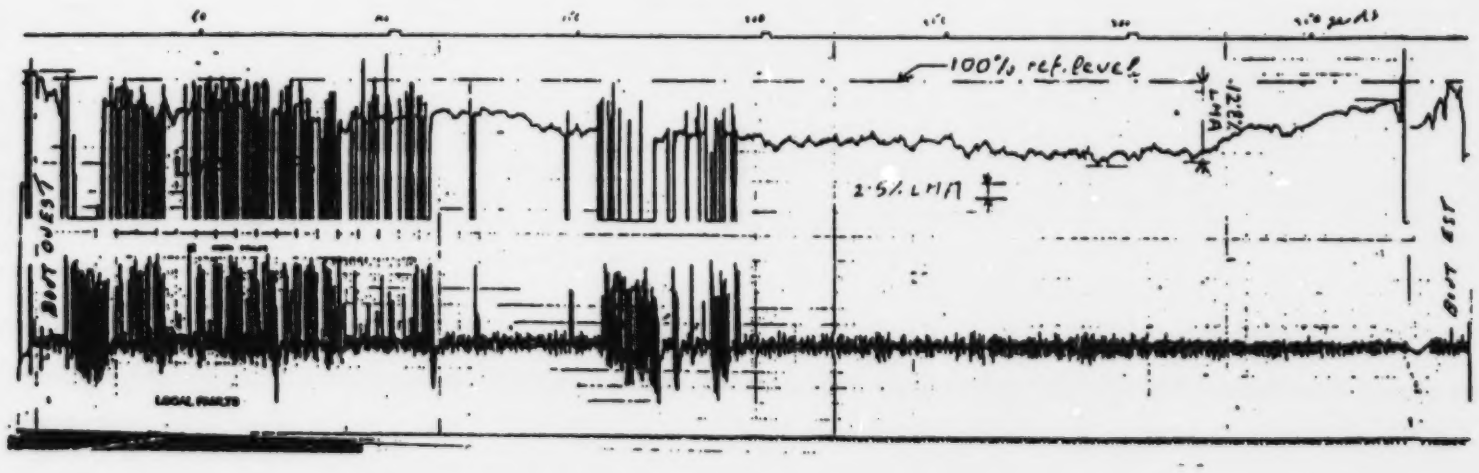


Fig. 1 (continued) — Magnograph testing of rope #13 **(c_2) 1989 03 14 test #89-169B, test #2; rope length = 378 yards (1,134 ft)**

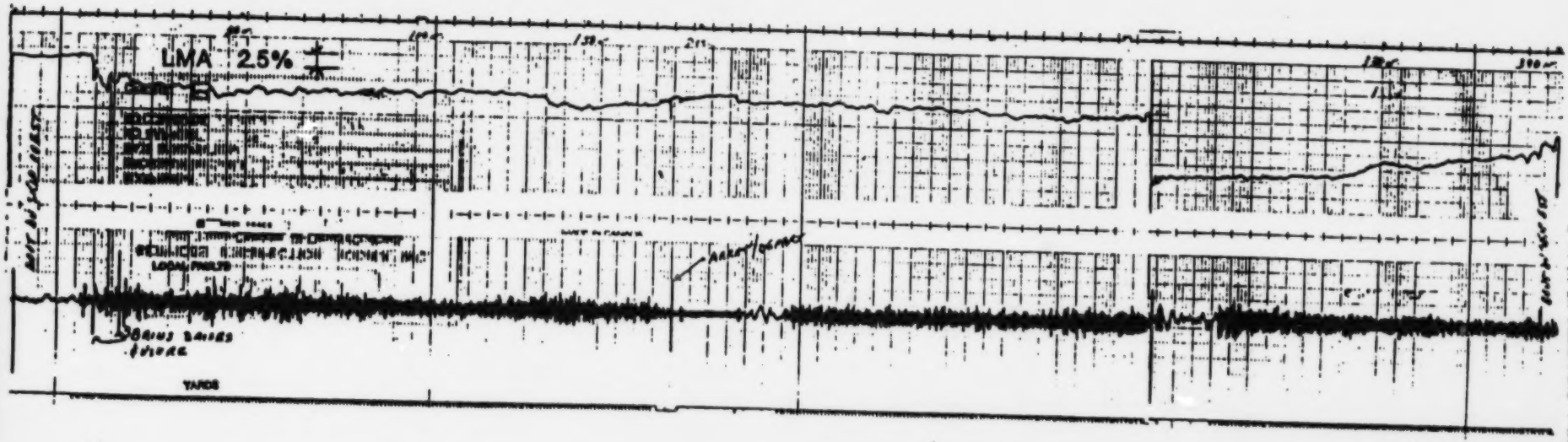


(a) 1988 05 25 test #88-256C; rope length = 381 yards (1,143 ft)



(b) 1988 09 21 test #88-463M; rope length = 385 yards (1,155 ft)

Fig. 2 -- Magnograph testing of rope #14



(c_1) 1989 03 14 test #89-169A, test #1; rope length = 380 yards (1,140 ft)

Fig. 2 (continued) — Magnograph testing of rope #14

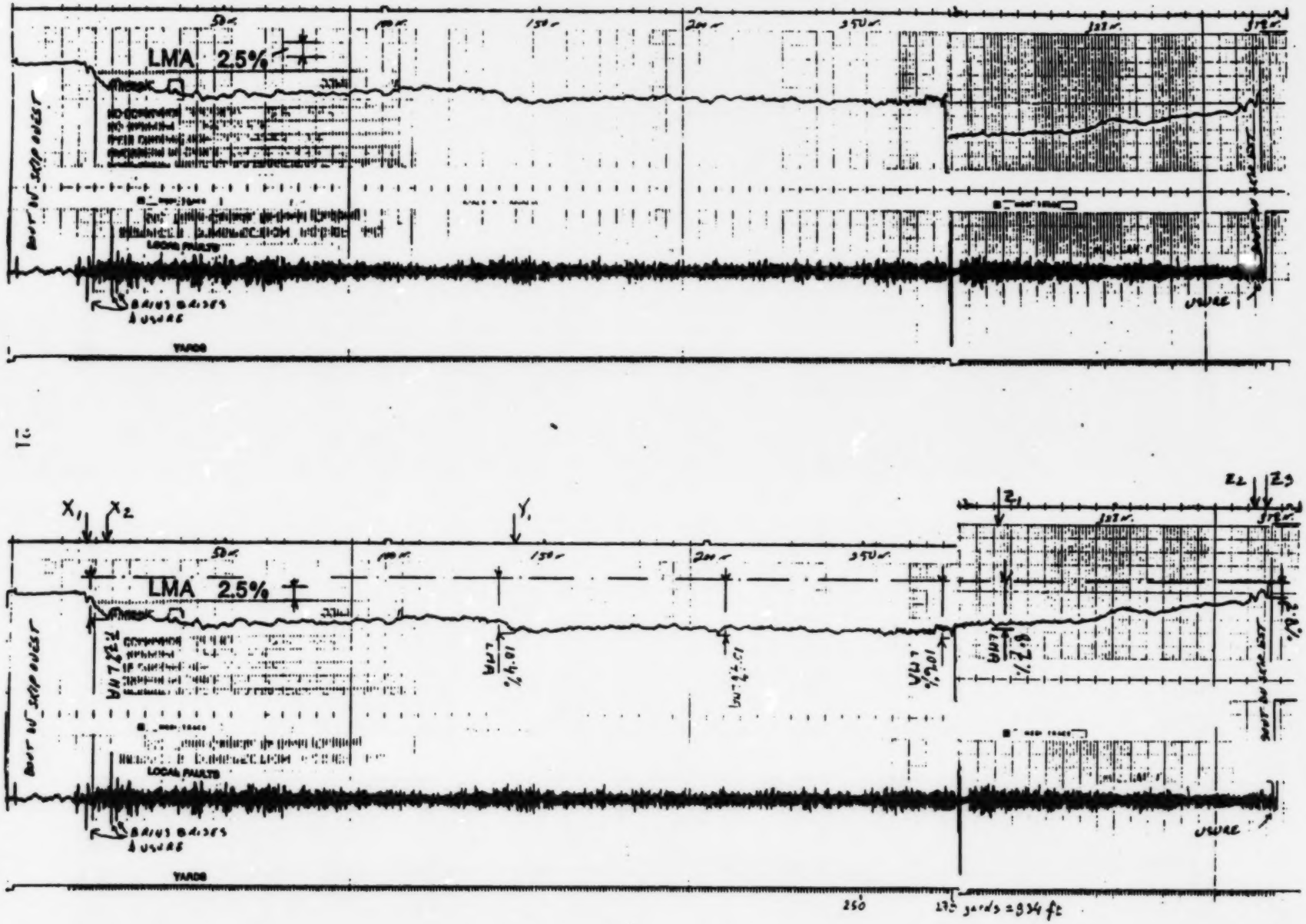


Fig. 2 (continued) -- Maguograph testing of rope #14 (c_2) 1989 03 14 test #89-169A, test #2; rope length = 378 yards (1,134 ft)

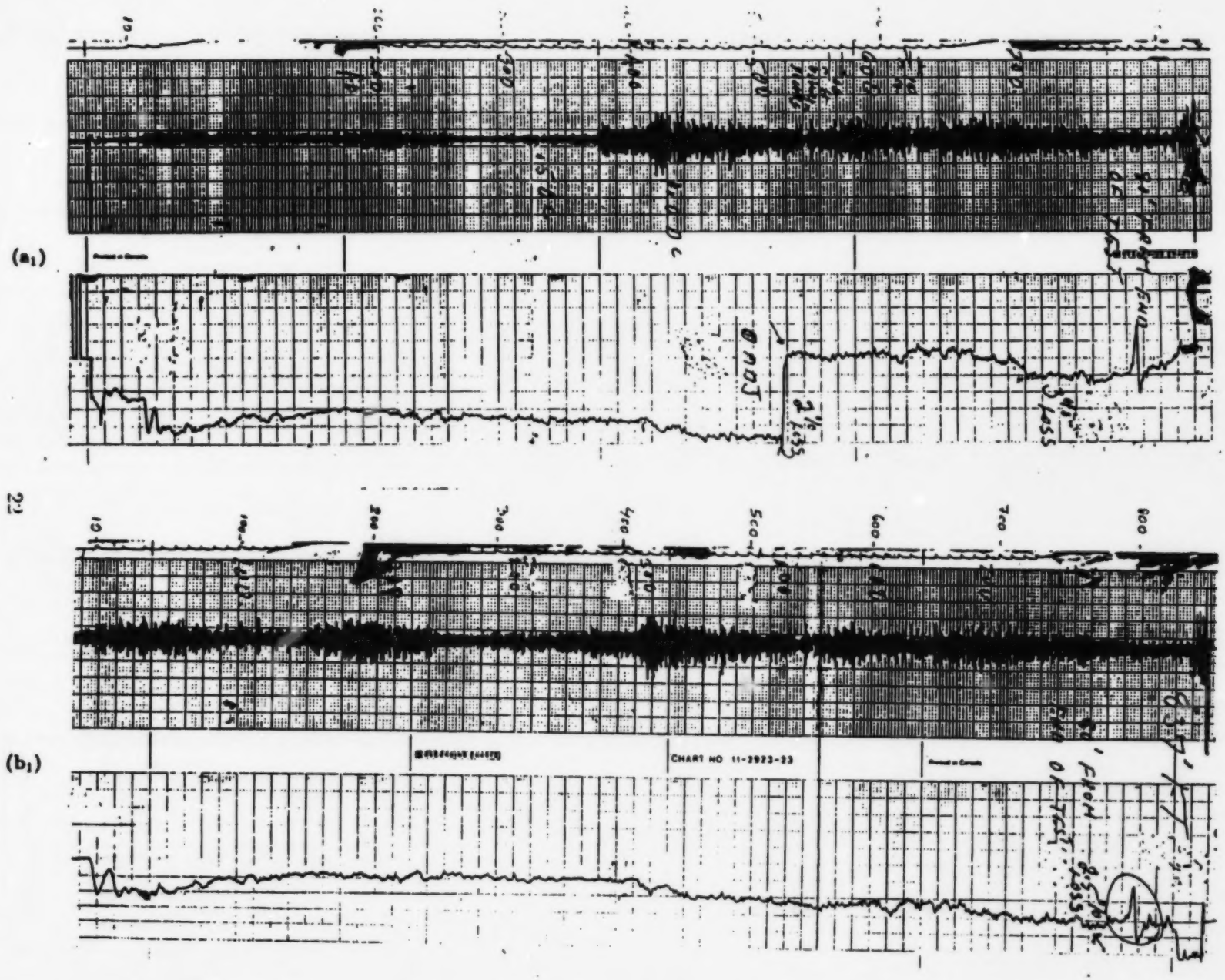
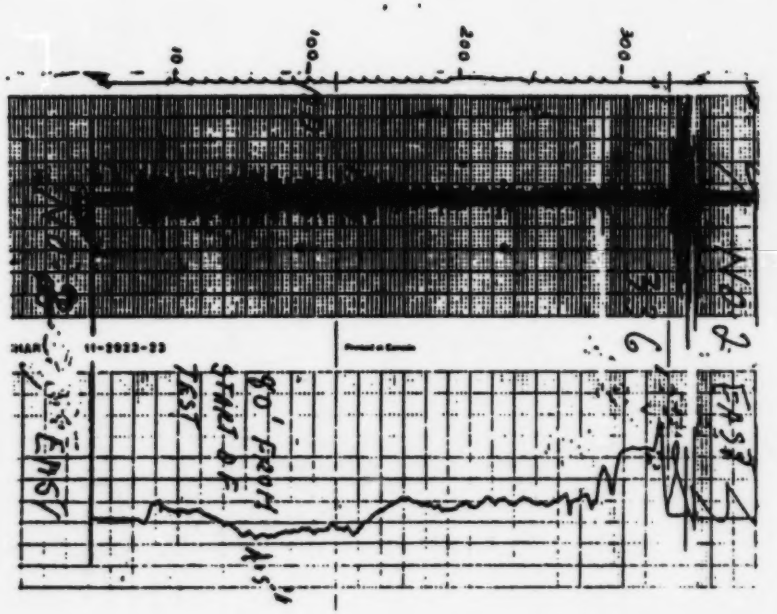
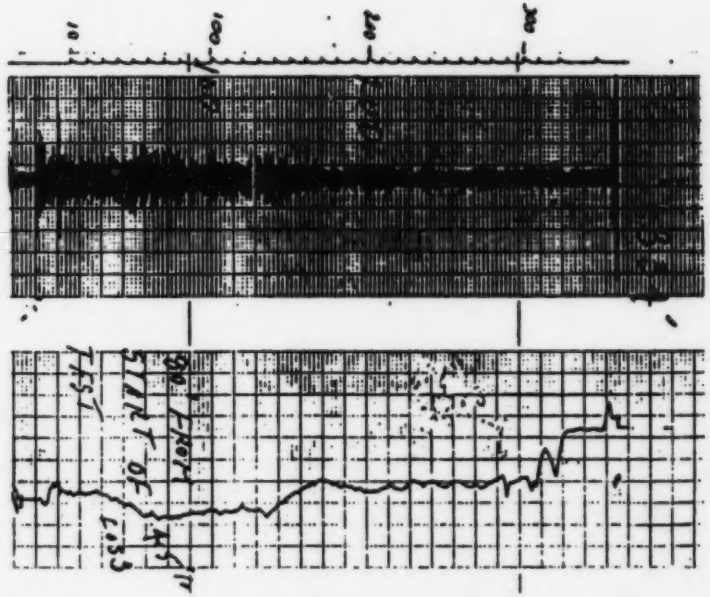


Fig. 3 — 1989 03 15 Rotescograph testing of rope #13; West-skip rope-end, as reported: (a_1) test #1, (b_1) test #2



(a$_2$)



(b$_2$)

Fig. 3 (continued) — 1989 03 15 Rotescograph testing of rope #13;

East-skip rope-end, as reported: (a$_2$) test #1, (b$_2$) test #2

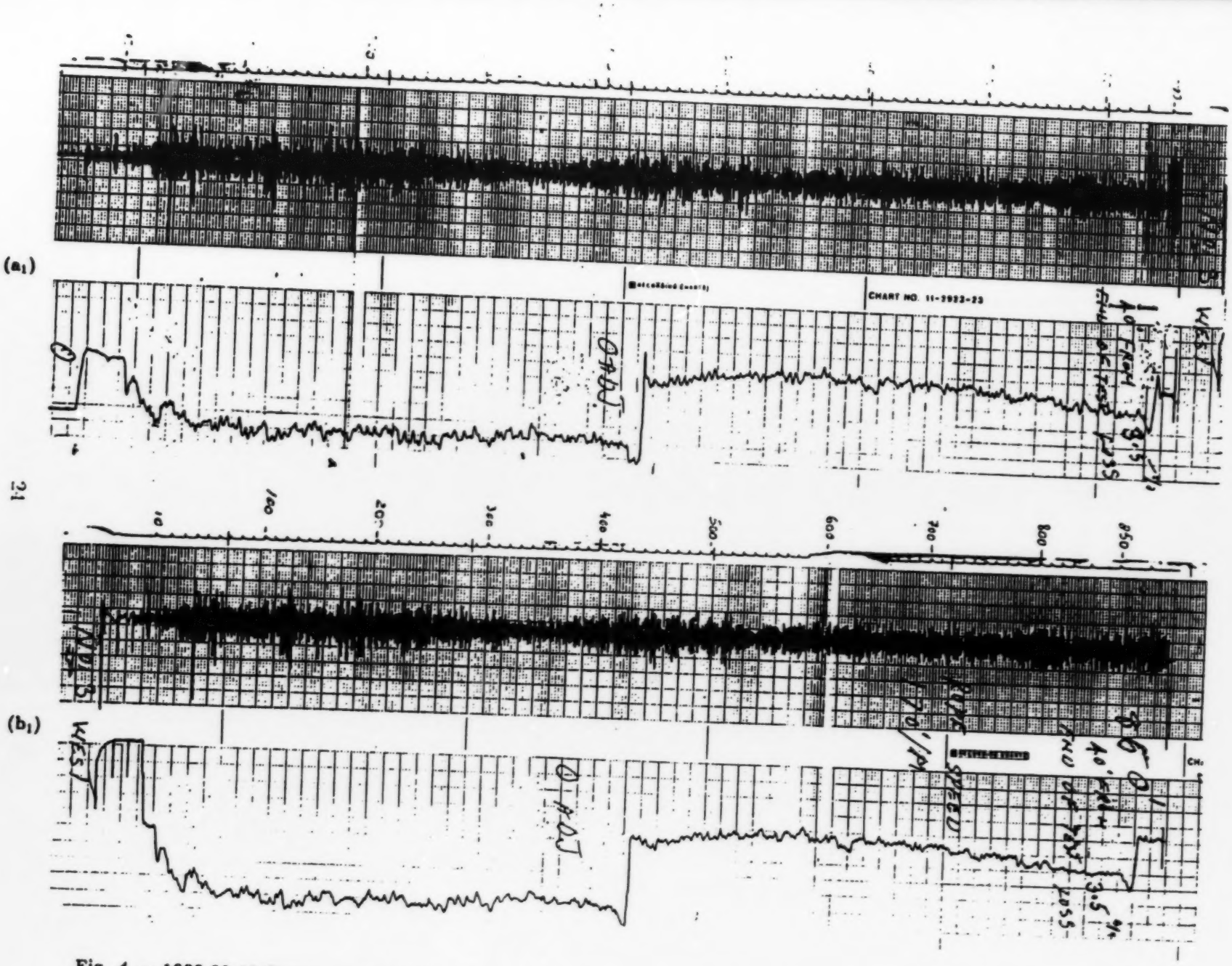
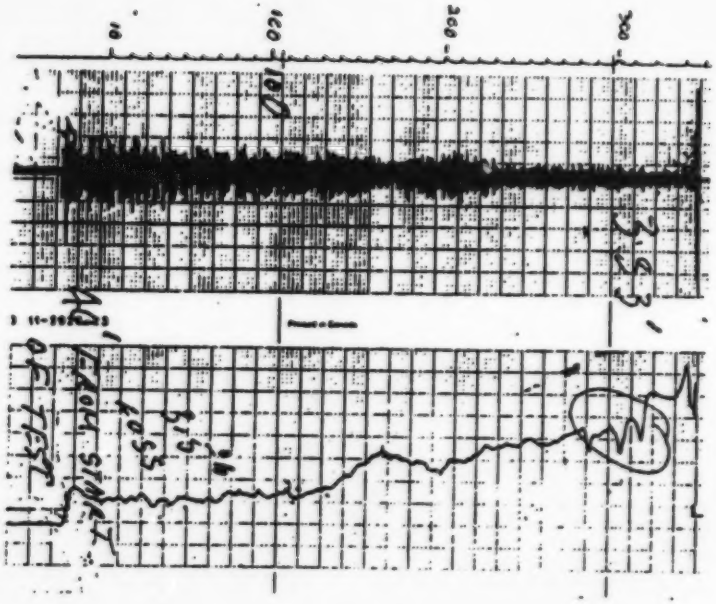
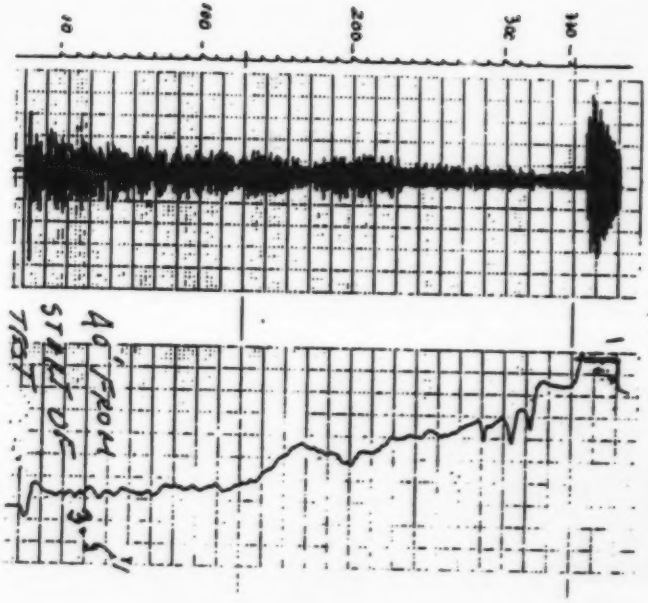


Fig. 4 — 1989 03 15 Rotescograph testing of rope #14; West-skip rope-end, as reported: (a_1) test #1, (b_1) test #2



(a_2)



(b_2)

Fig. 4 (continued) — 1989 03 15 Rotescograph testing of rope #14;

East-skip rope-end, as reported: (a_2) test #1, (b_2) test #2

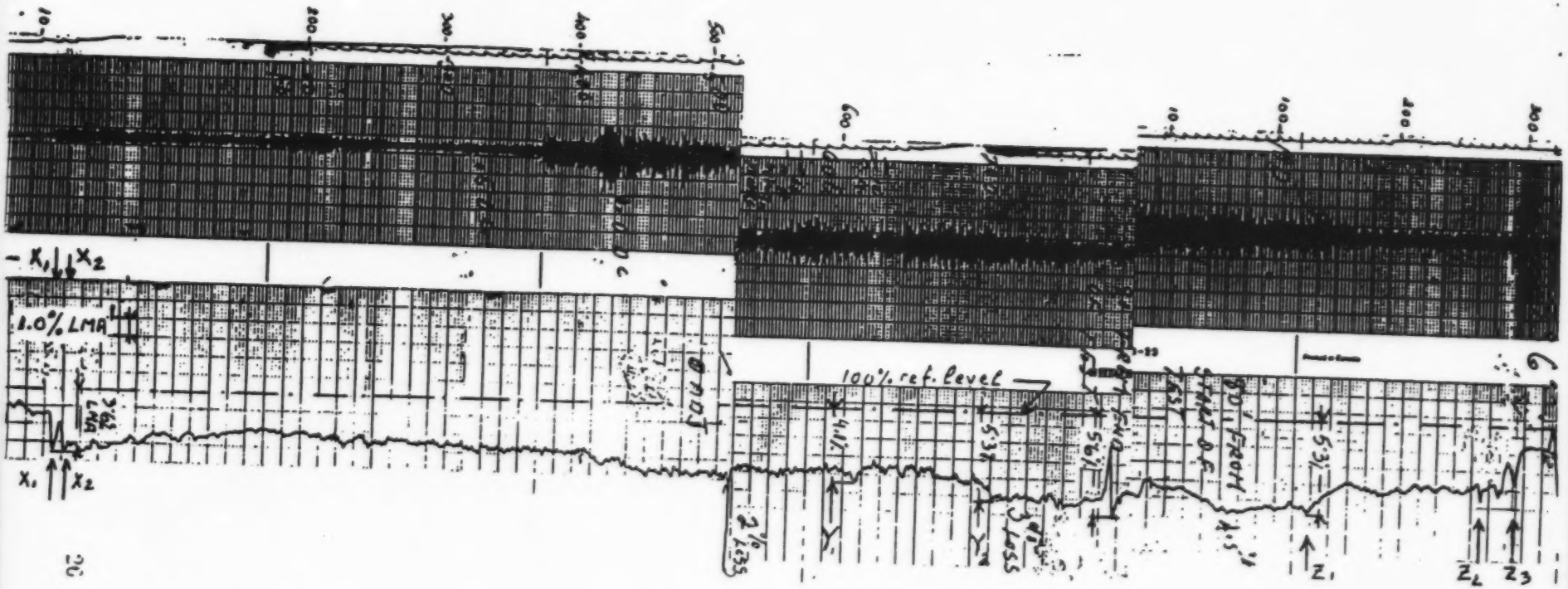


Fig. 5a — 1989 03 15 Rotescograph test #1 of rope #13; as aligned and marked by authors

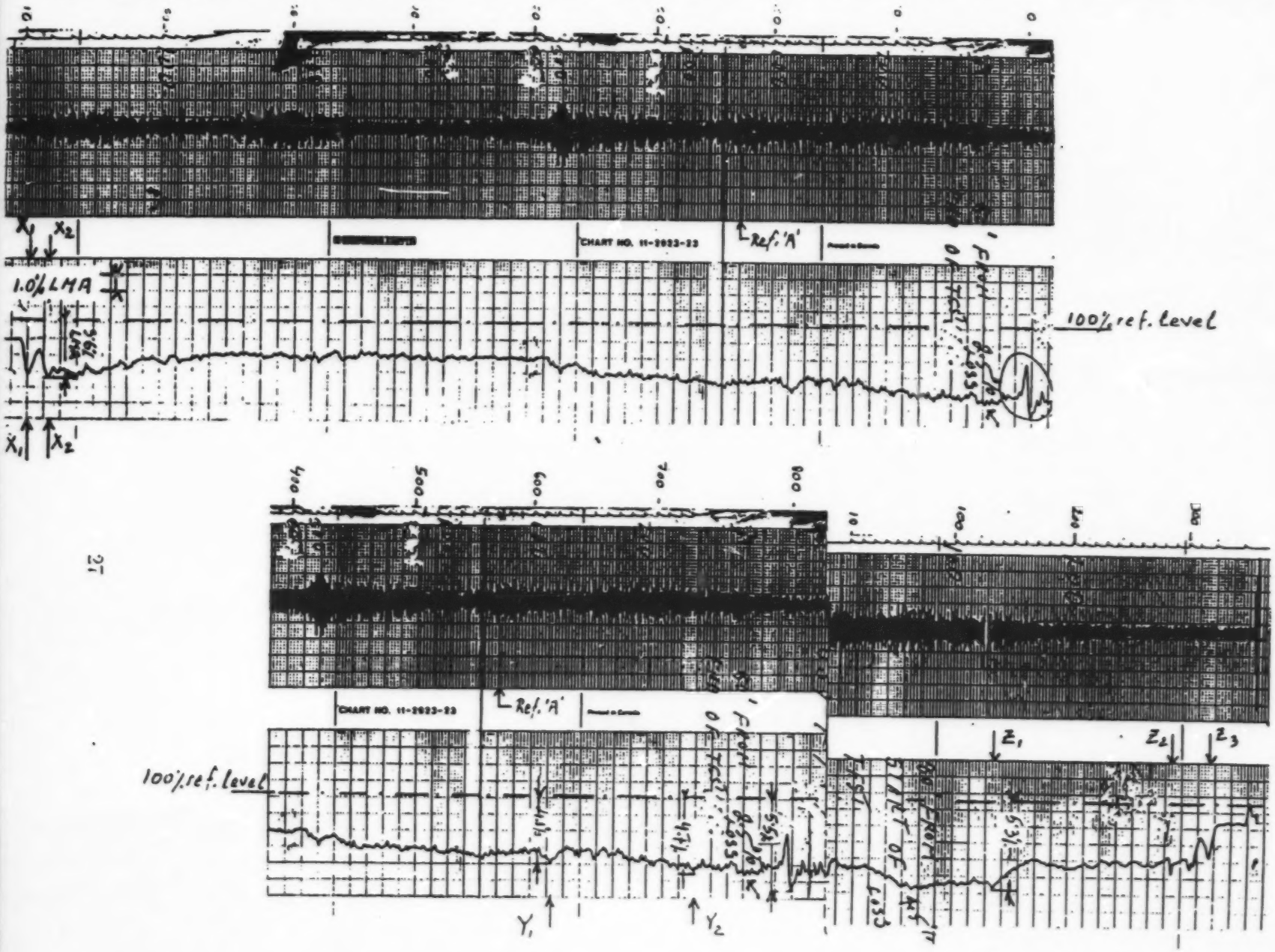


Fig. 5b — 1989 03 15 Rotescograph test #2 of rope #13; as aligned and marked by authors

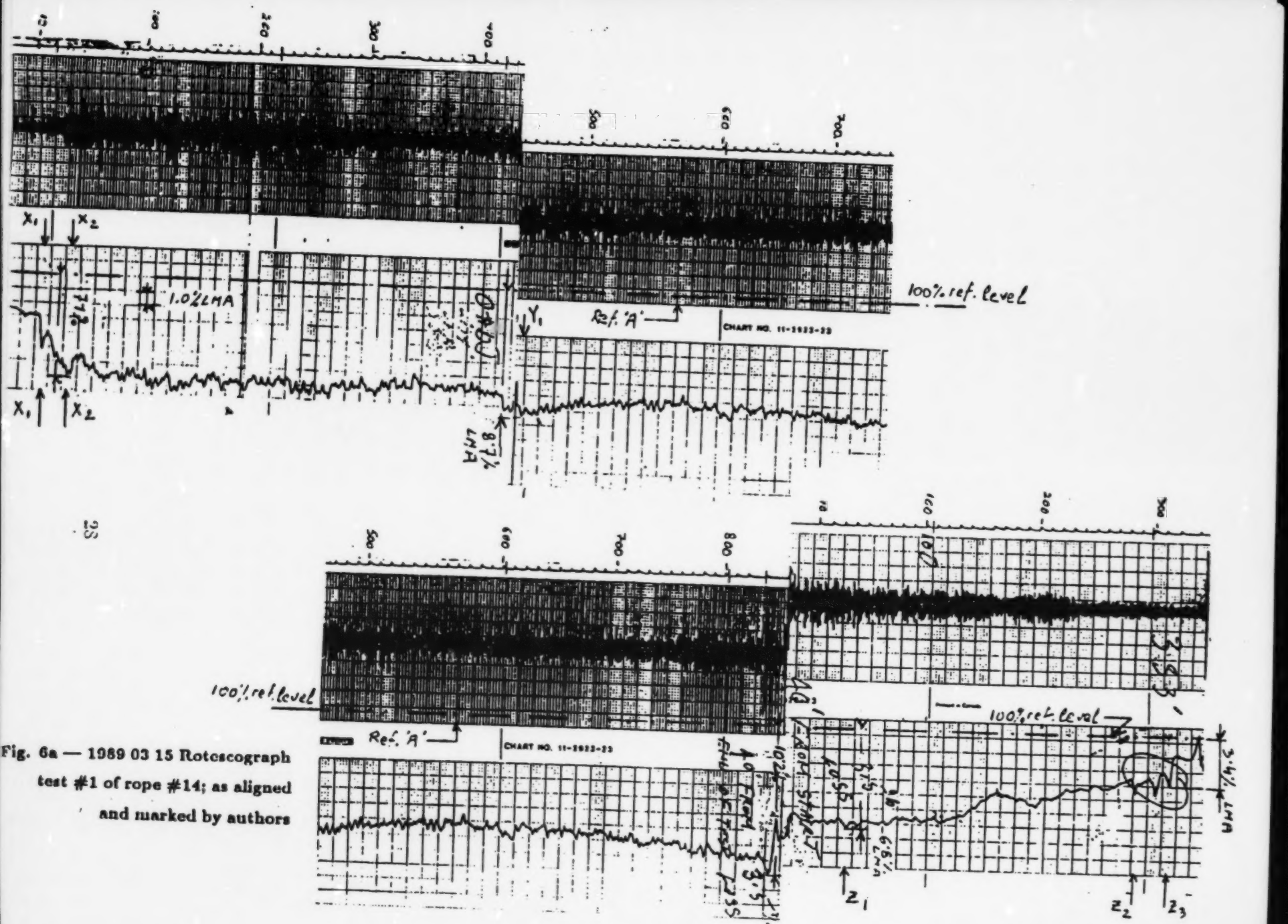


Fig. 6a — 1969 03 15 Rotoscograph test #1 of rope #14; as aligned and marked by authors

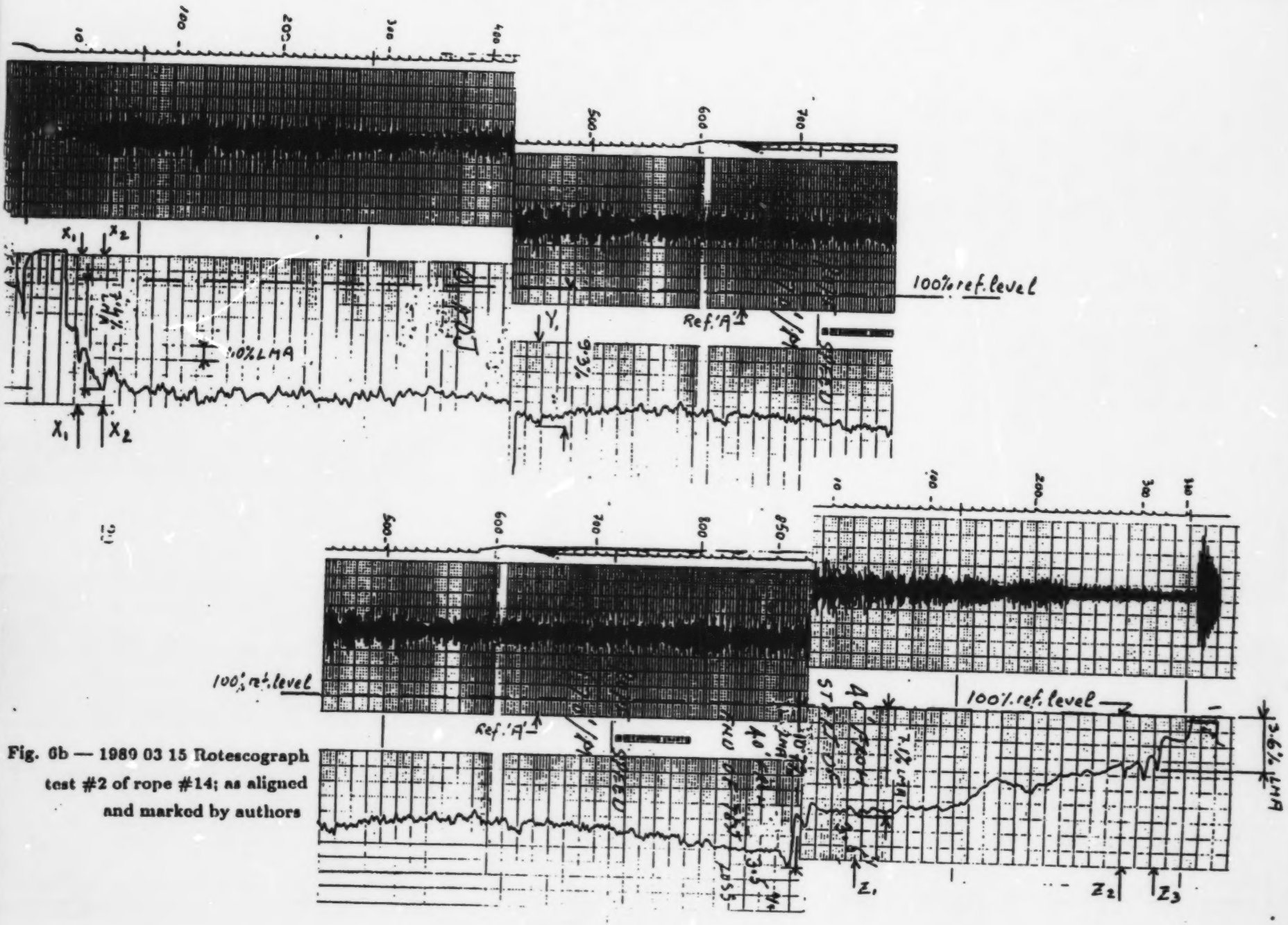


Fig. 6b — 1989 03 15 Rotescograph test #2 of rope #14; as aligned and marked by authors

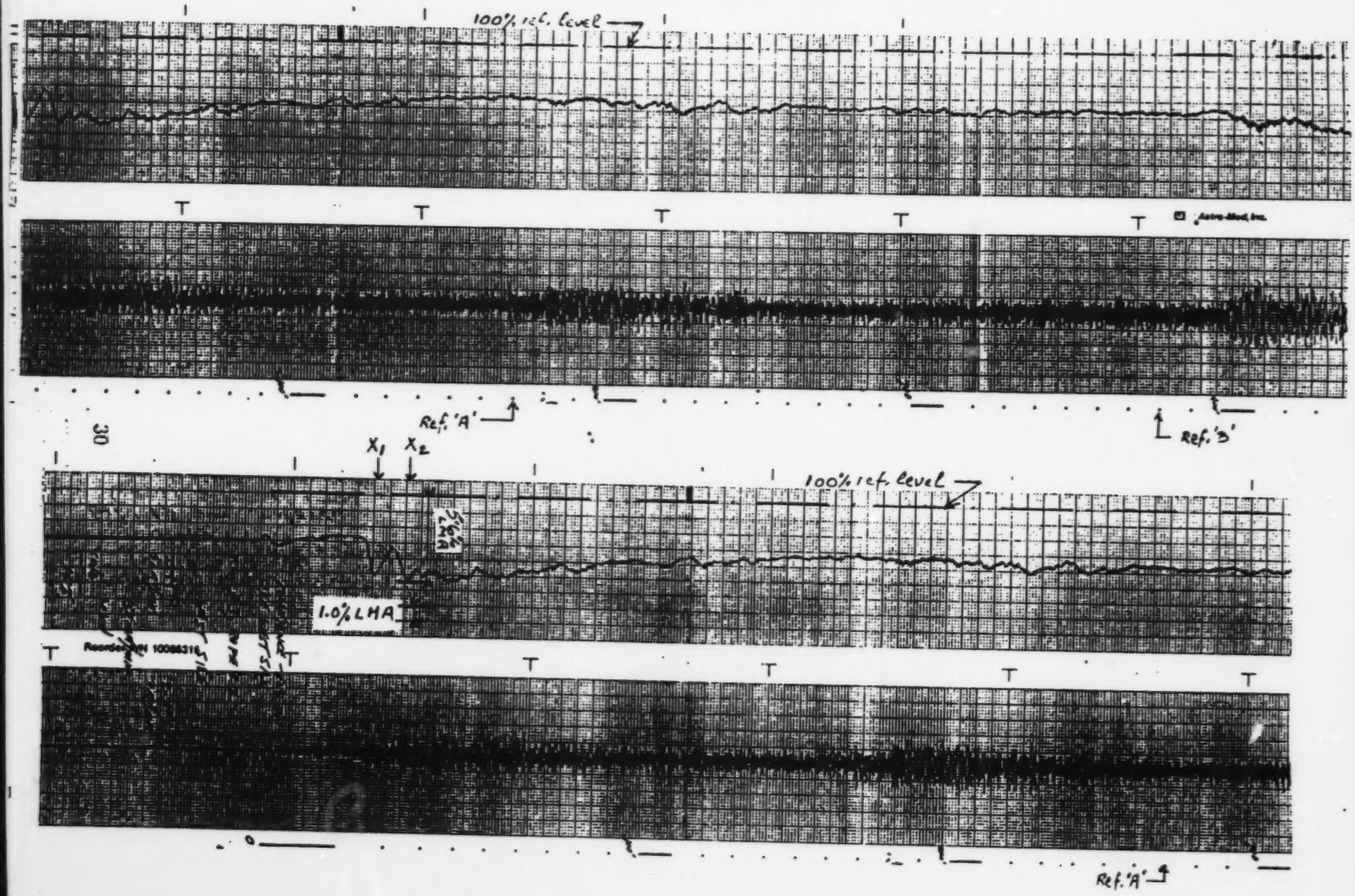


Fig. 7 — 1989 0315 LMA-250 testing of rope #13; West-skip rope-end = run #3, East-skip rope-end = run #8

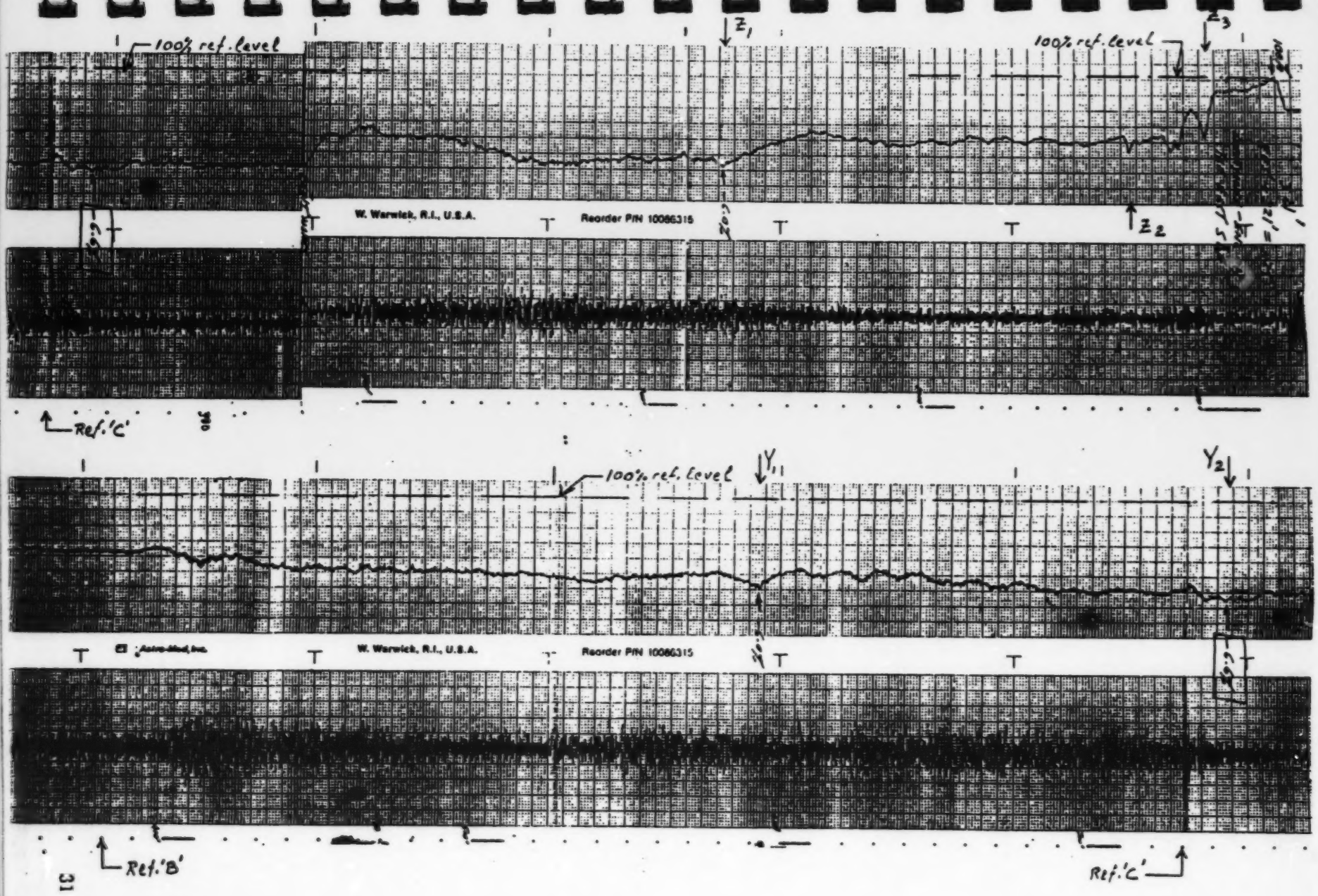


Fig. 7 (continued) — 1989 03 15 LMA-250 testing of rope #13; West-skip rope-end = run #3, East-skip rope-end = run #8

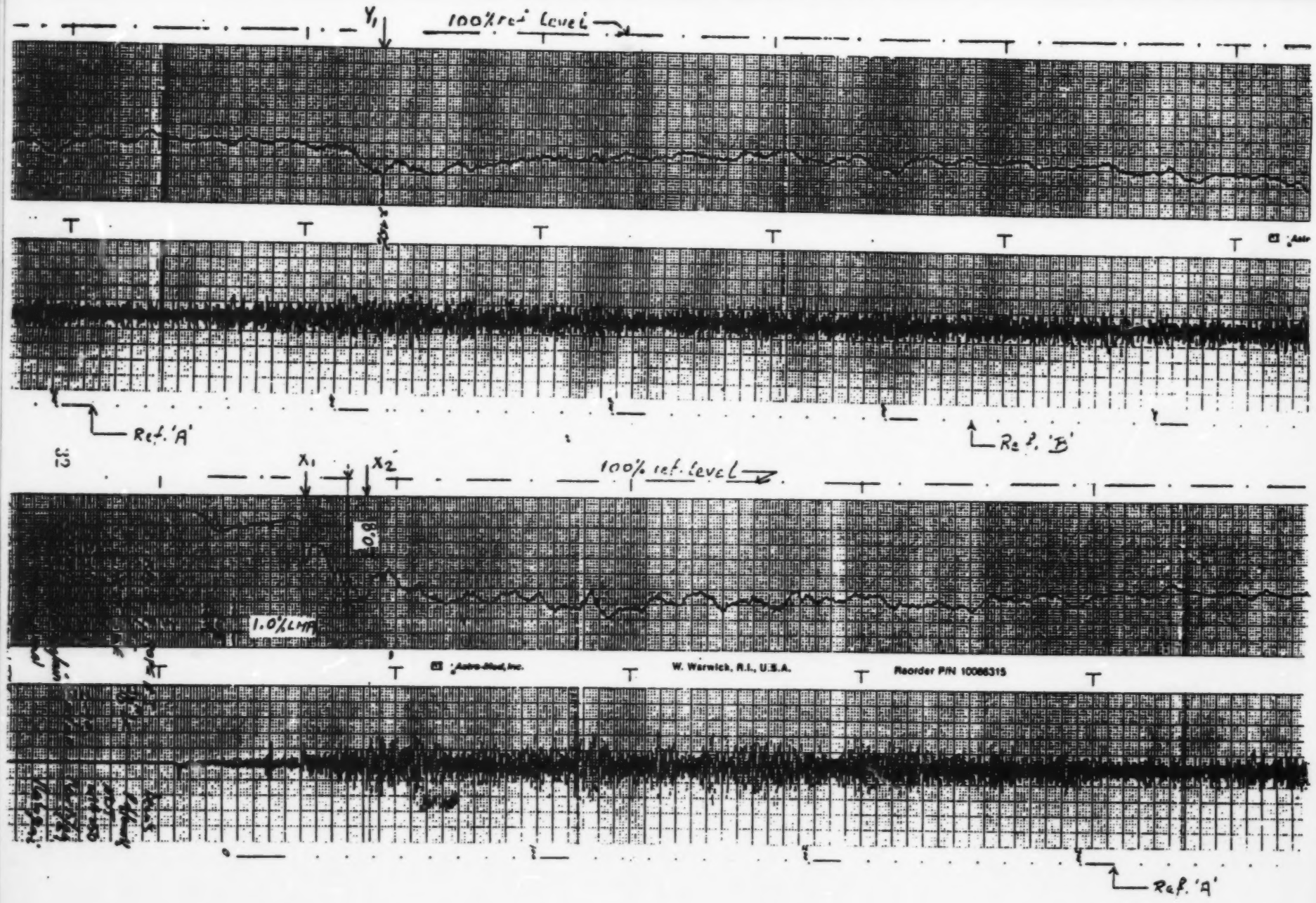


Fig. 8 — 1989 03 15 LMA-250 testing of rope #14; West-skip rope-end = run #5, East-skip rope-end = run #11

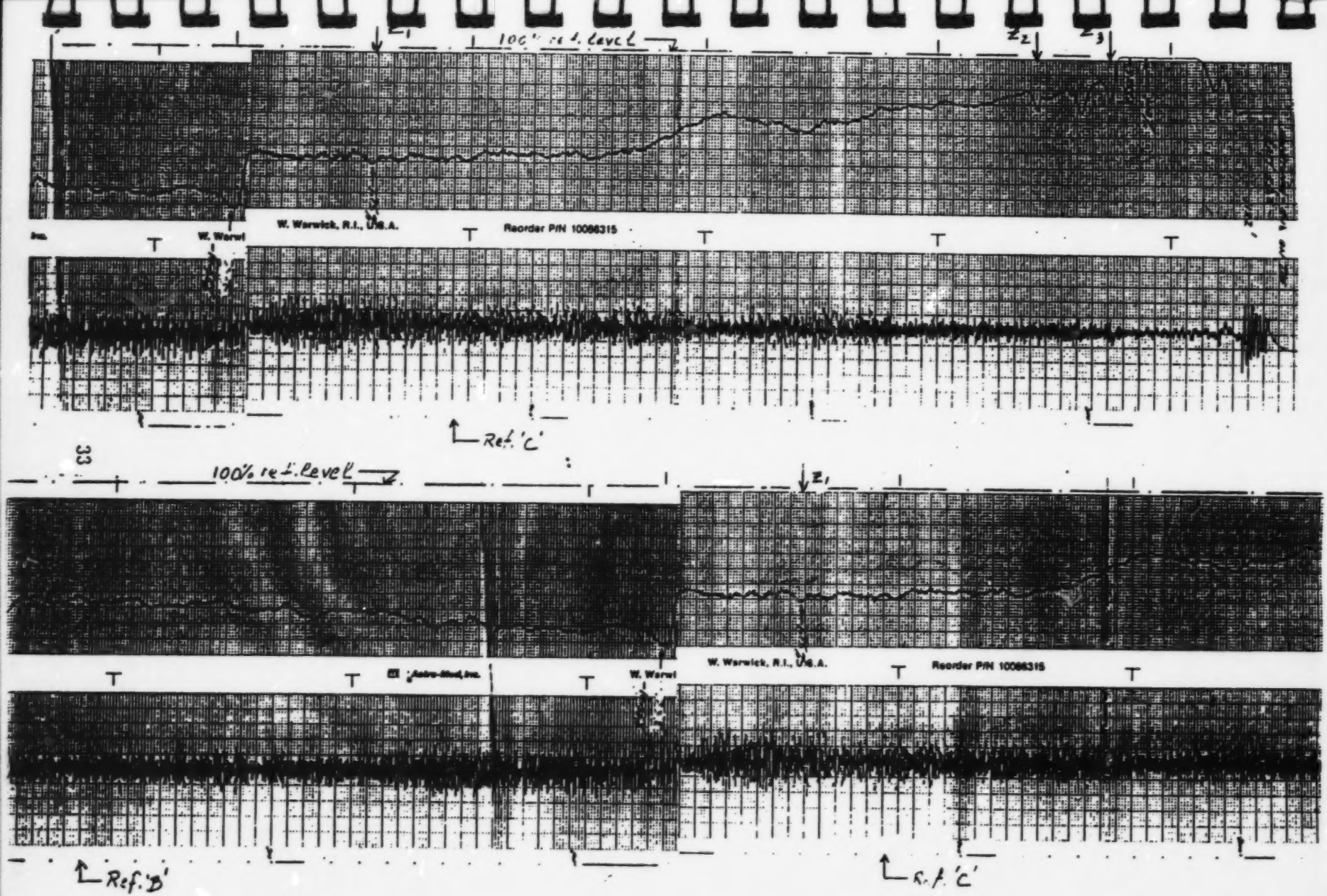


Fig. 8 (continued) — 1989 03 15 LMA-250 testing of rope #14: West-skip rope-end = run #5. East-skip rope-end = run #11

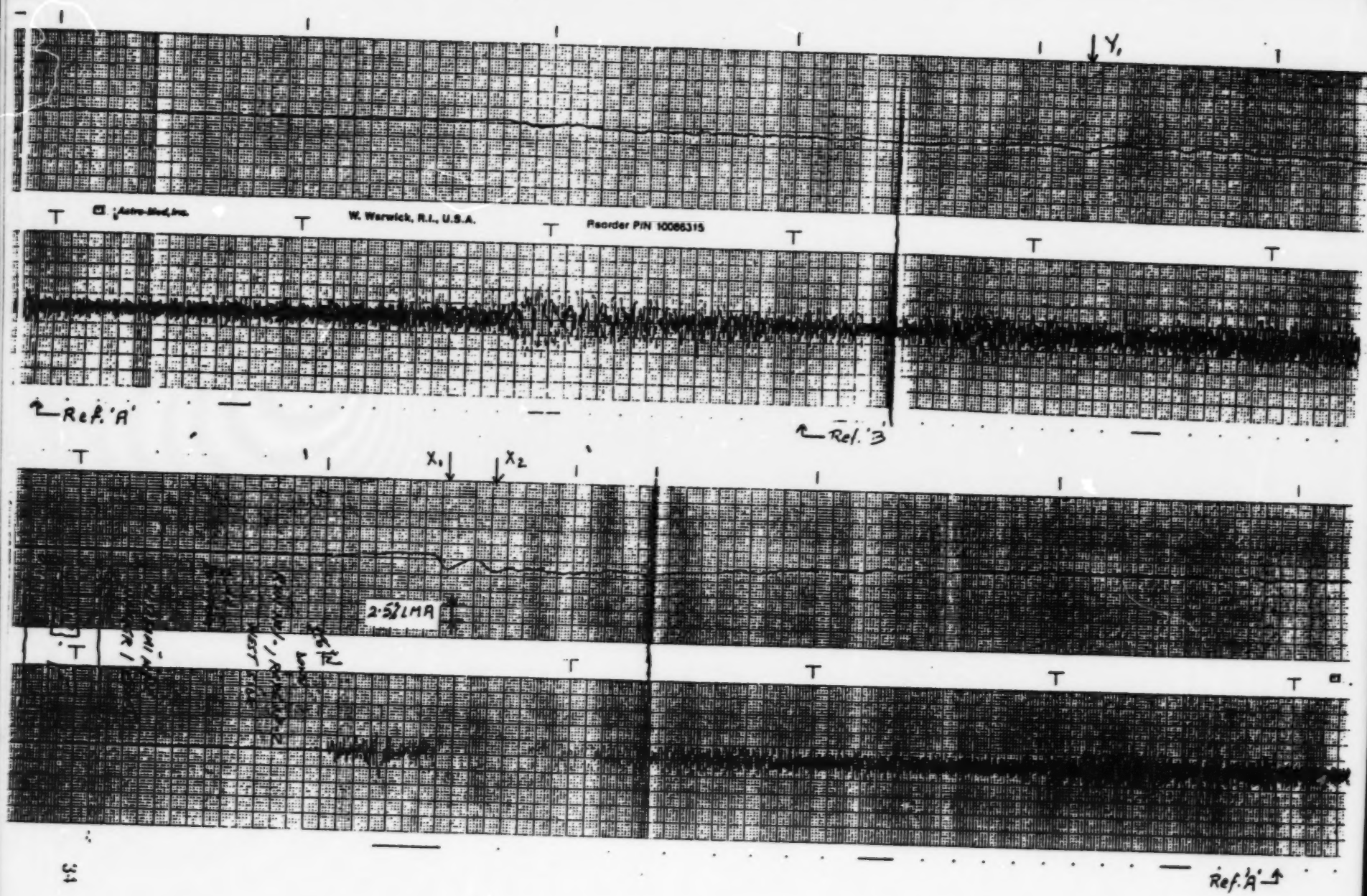


Fig. 9 --- 1989 03 15 LMA-250 testing of rope #13; West-skip rope-end: (a) run #1

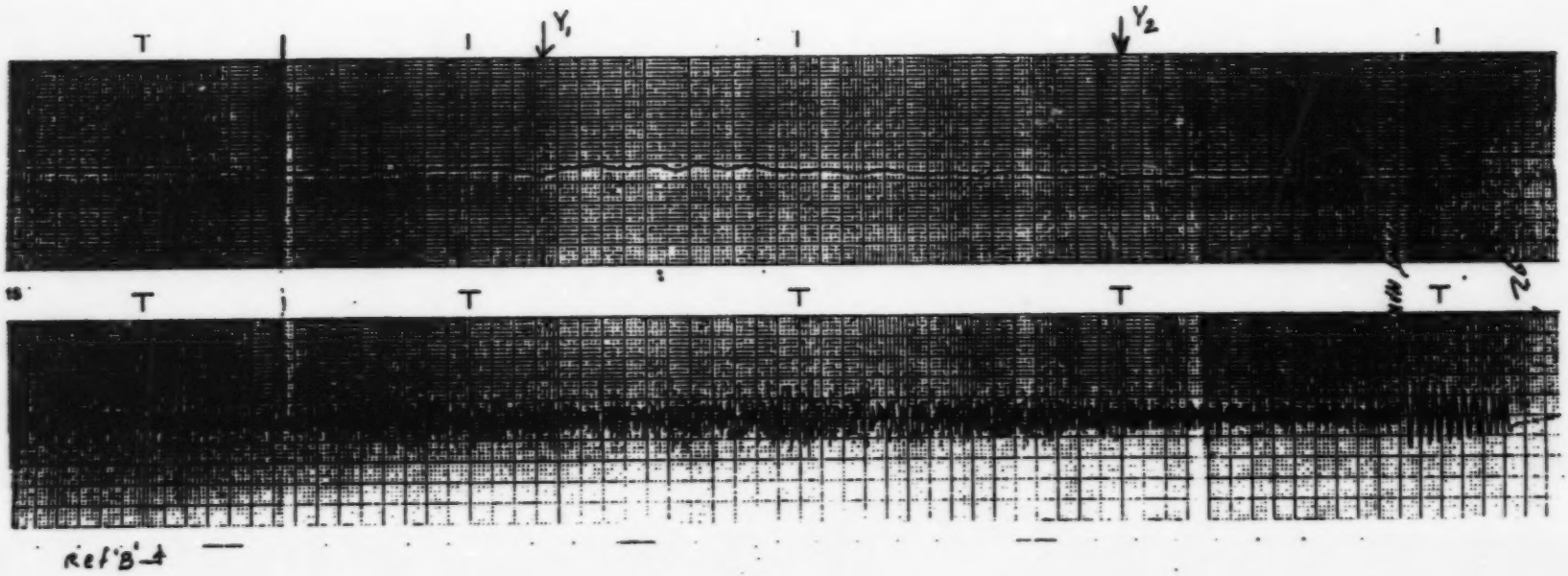


Fig. 9 (continued) — 1989 03 15 LMA-250 testing of rope #13; West-skip rope-end: (a) run #1

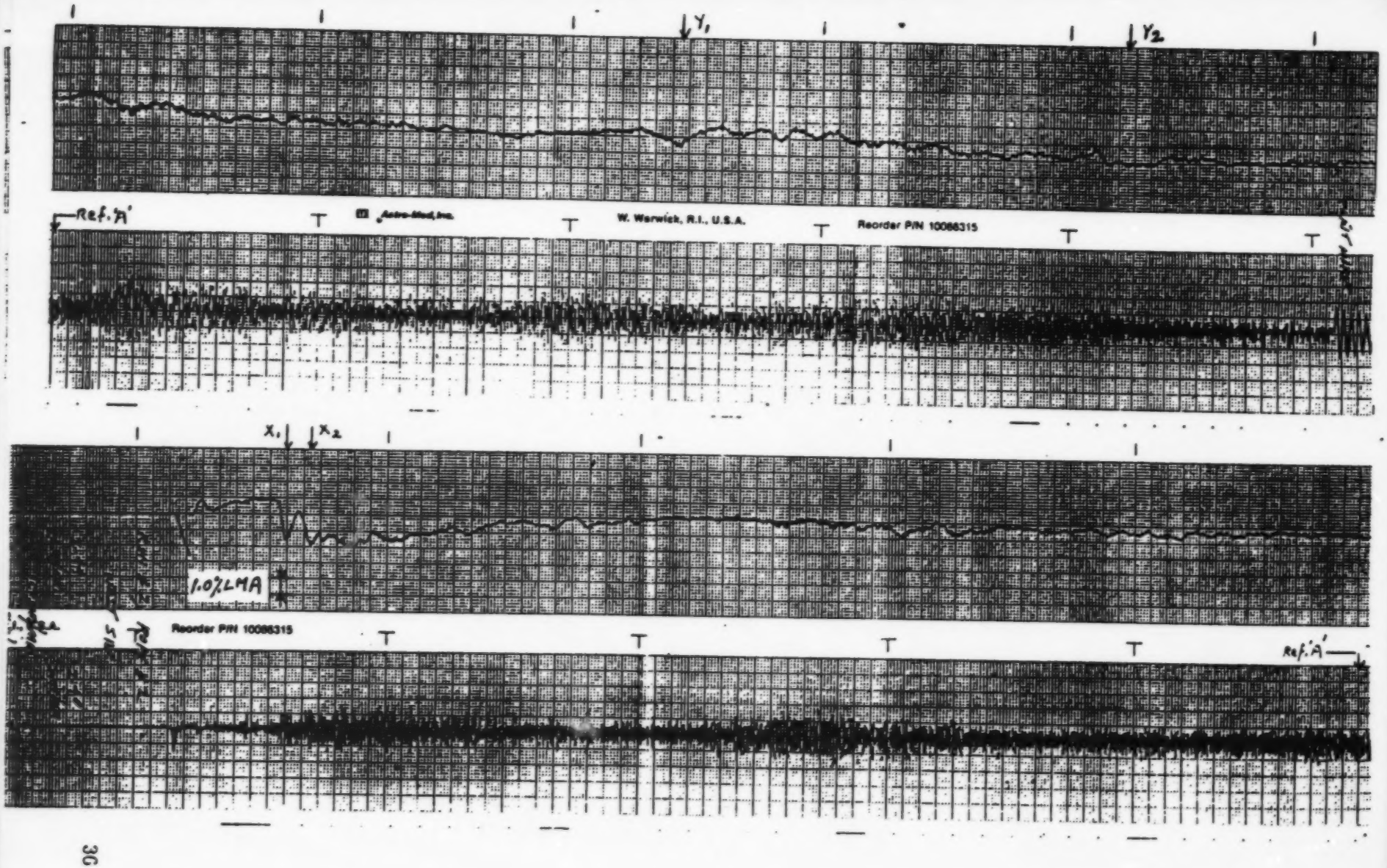


Fig. 9 (continued) — 1989 03 15 LMA-250 testing of rope #13; West-skip rope-end: (b) run #2

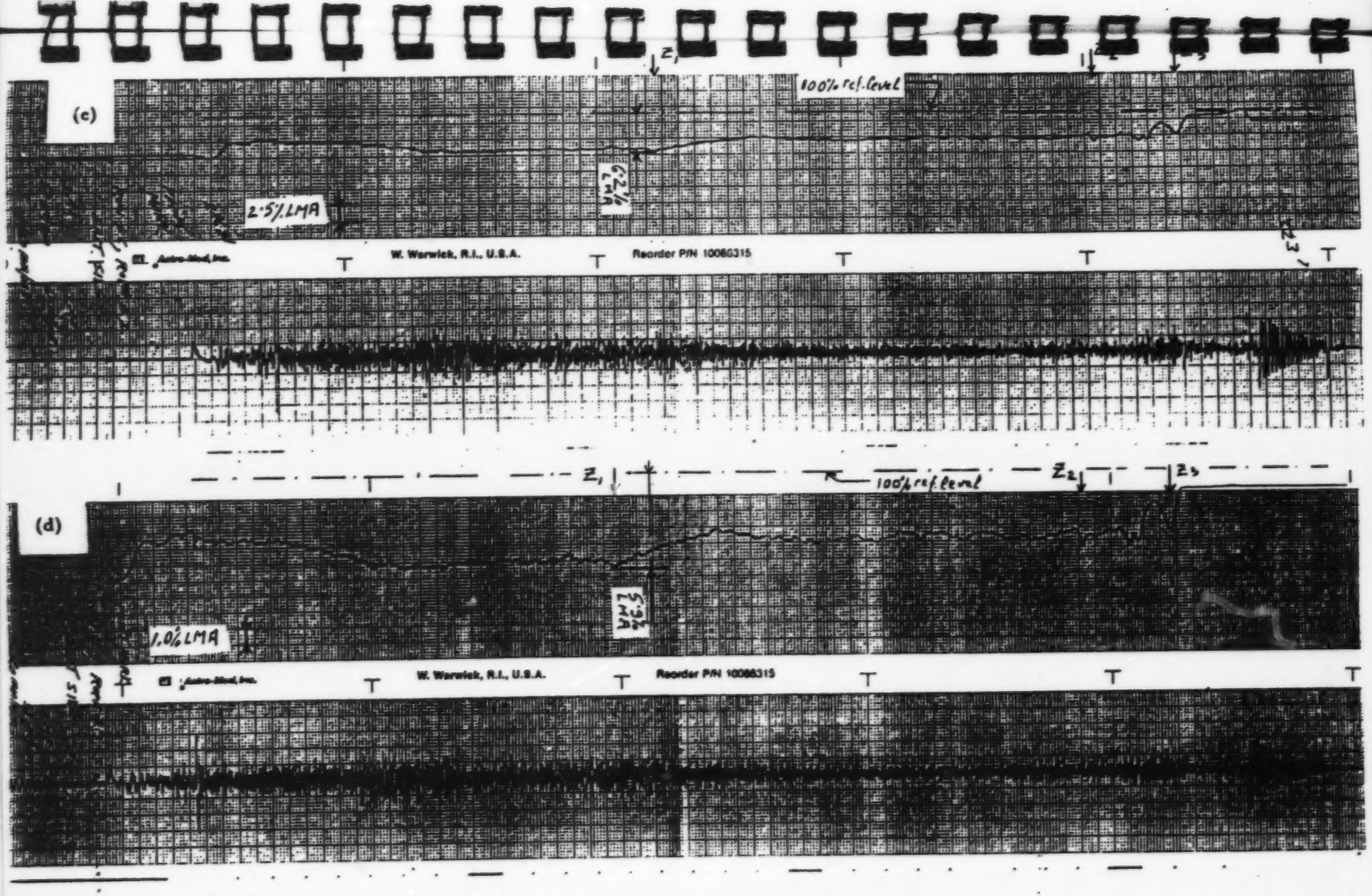


Fig. 9 (continued) — 1989 03 15 LMA-250 testing of rope #13: East-skip rope-end: (c) run #6, (d) run #7

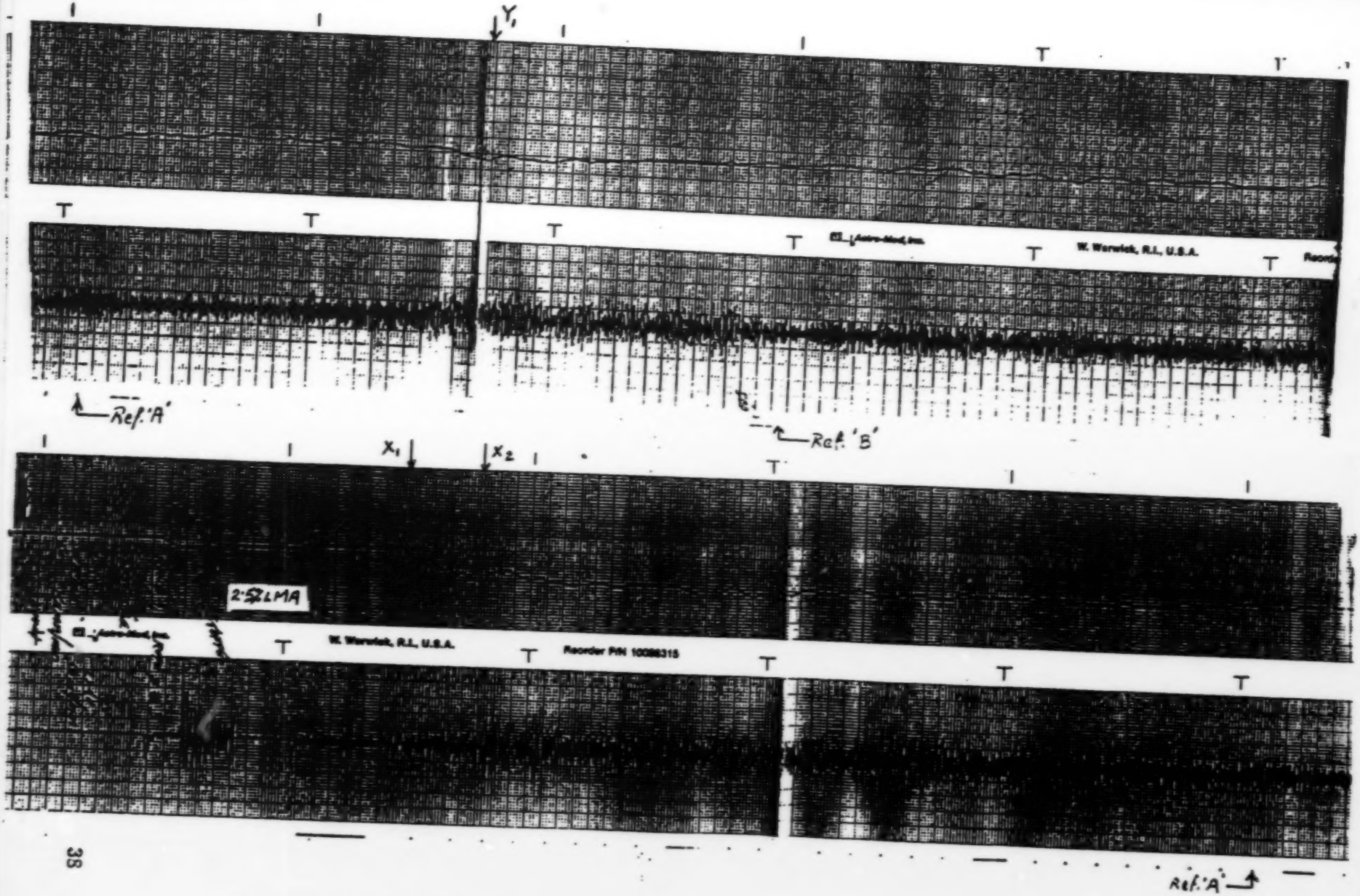


Fig. 10 — 1989 03 15 LMA-250 testing of rope #14; West-skip rope-end: (a) run #4

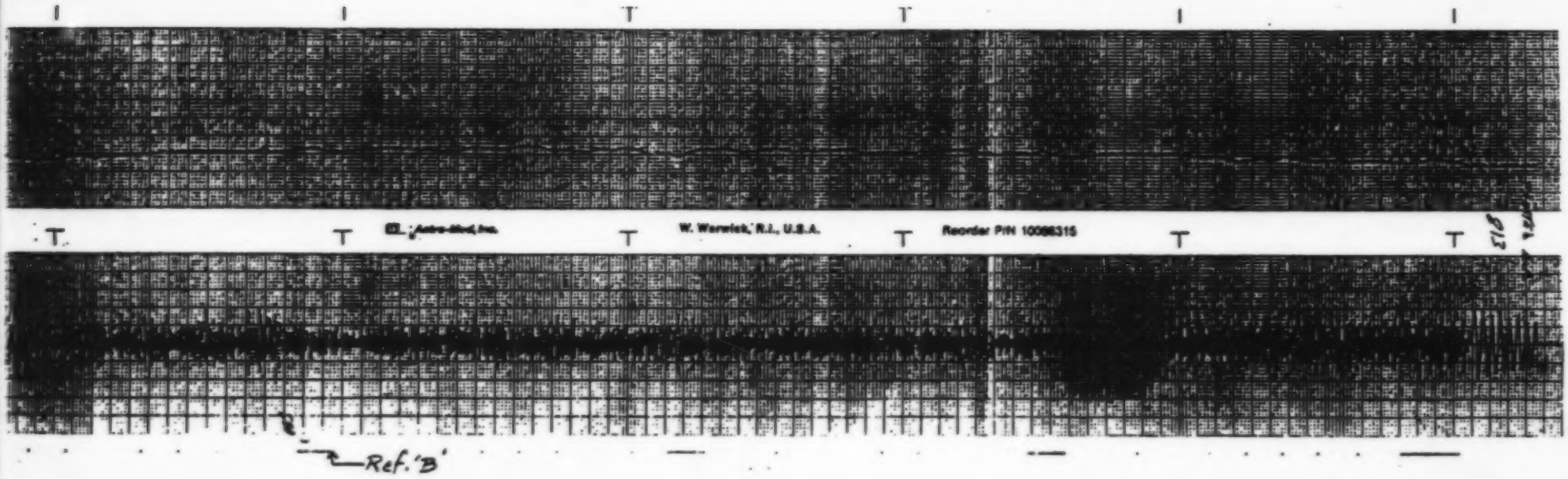


Fig. 10 (continued) — 1989 03 15 LMA-250 testing of rope #14; West-skip rope-end: (a) run #4

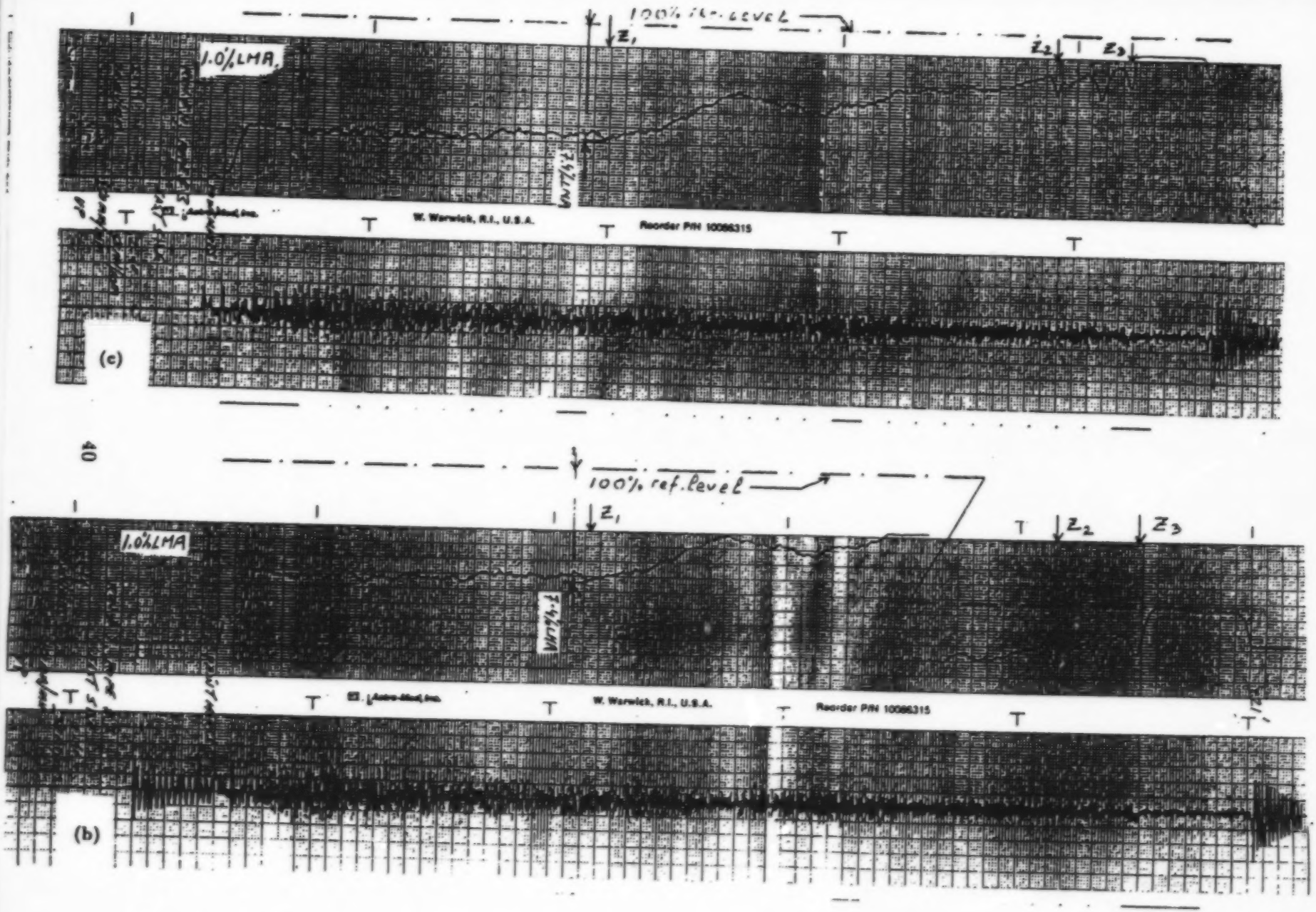


Fig. 10 (continued) — 1989 03 15 LMA-250 testing of rope #14; East-skip rope-end: (b) run #9, (c) run #10

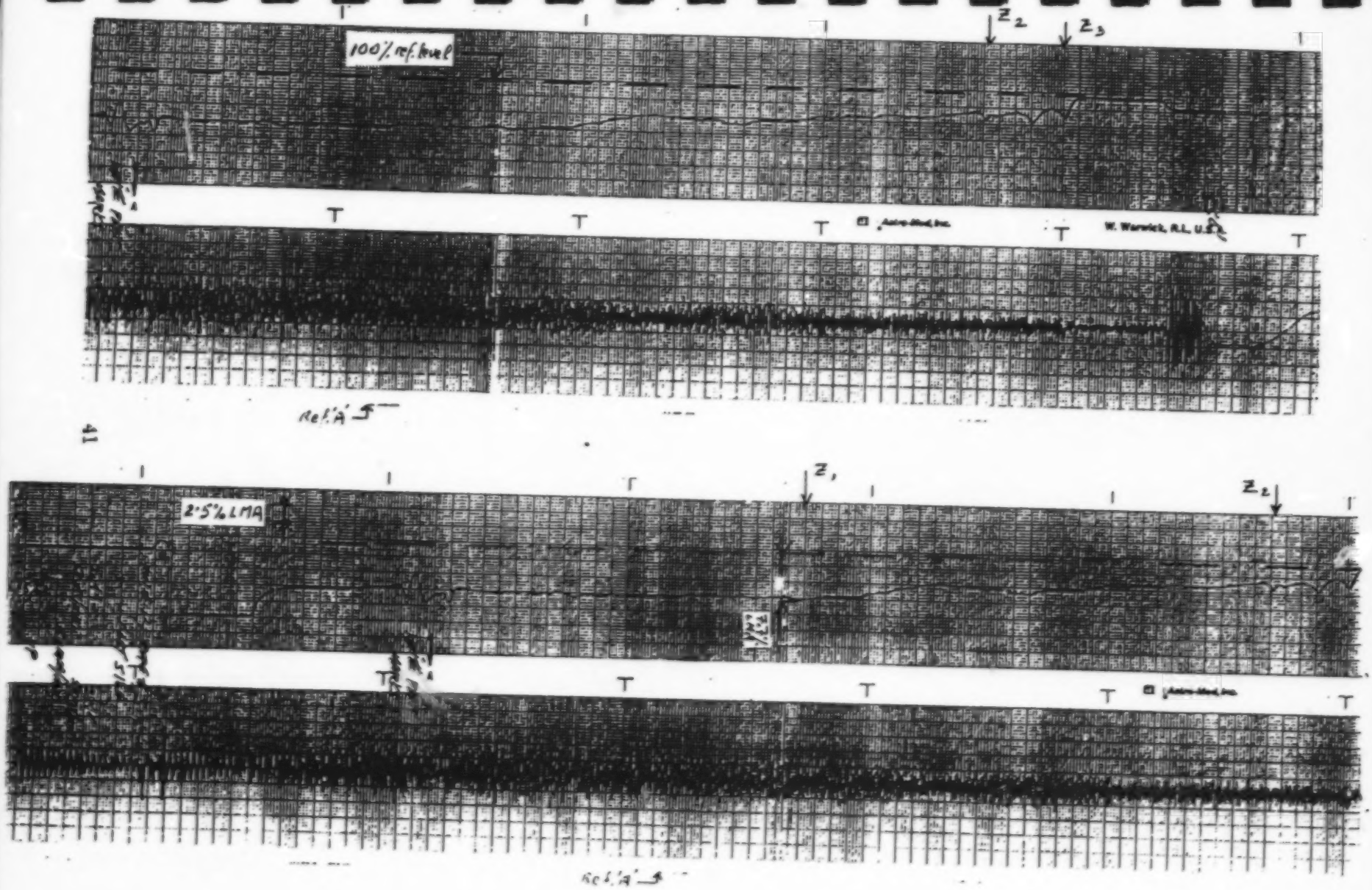


Fig. 10 (continued) — 1989 03 15 LMA-250 testing of rope #14: East-skip rope-end: (b) run #12

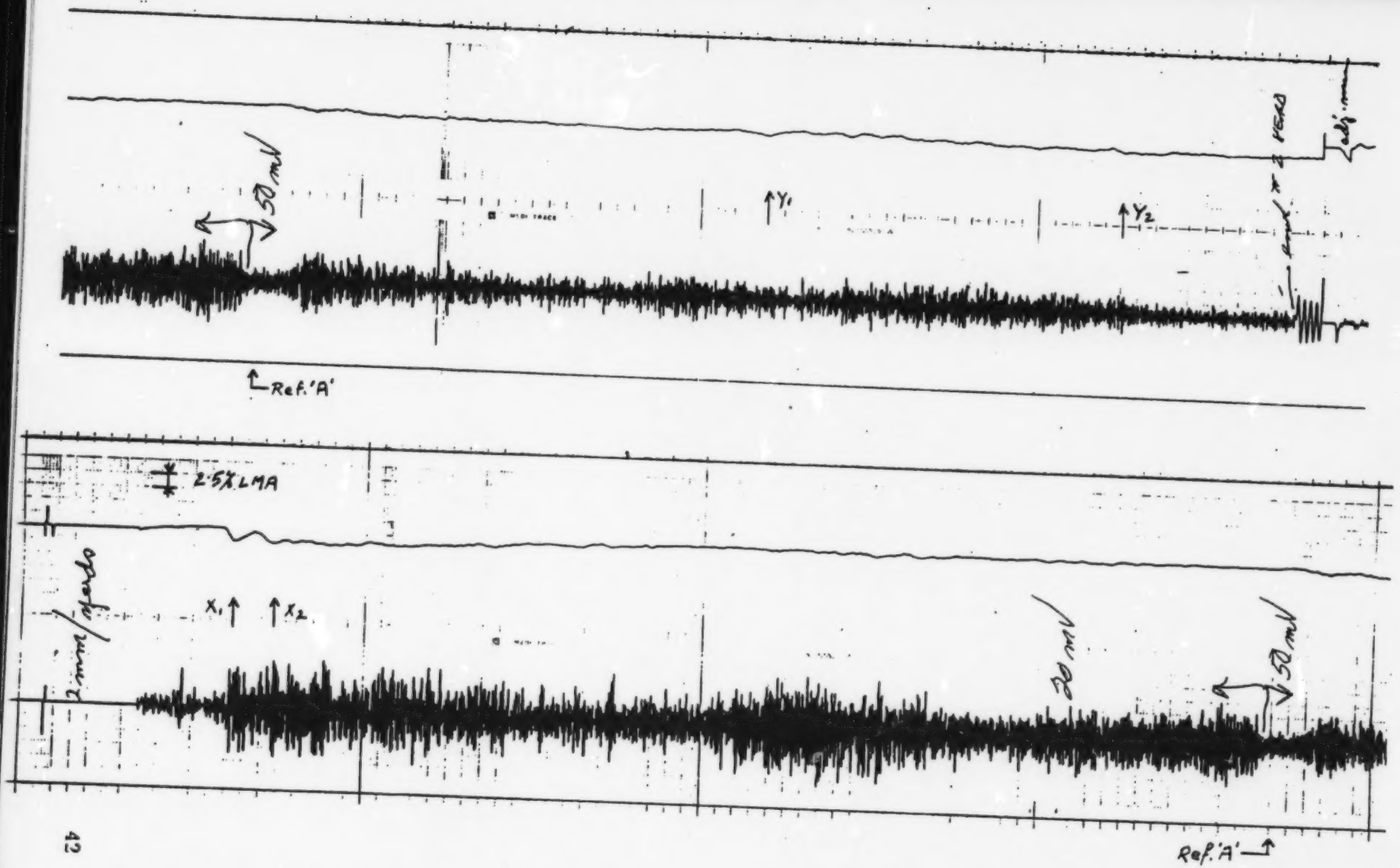


Fig. 11 — 1989 03 15 LMA-250 test #1 of rope #13; West-skip rope-end with Magnograph's *Gould 222* recorder

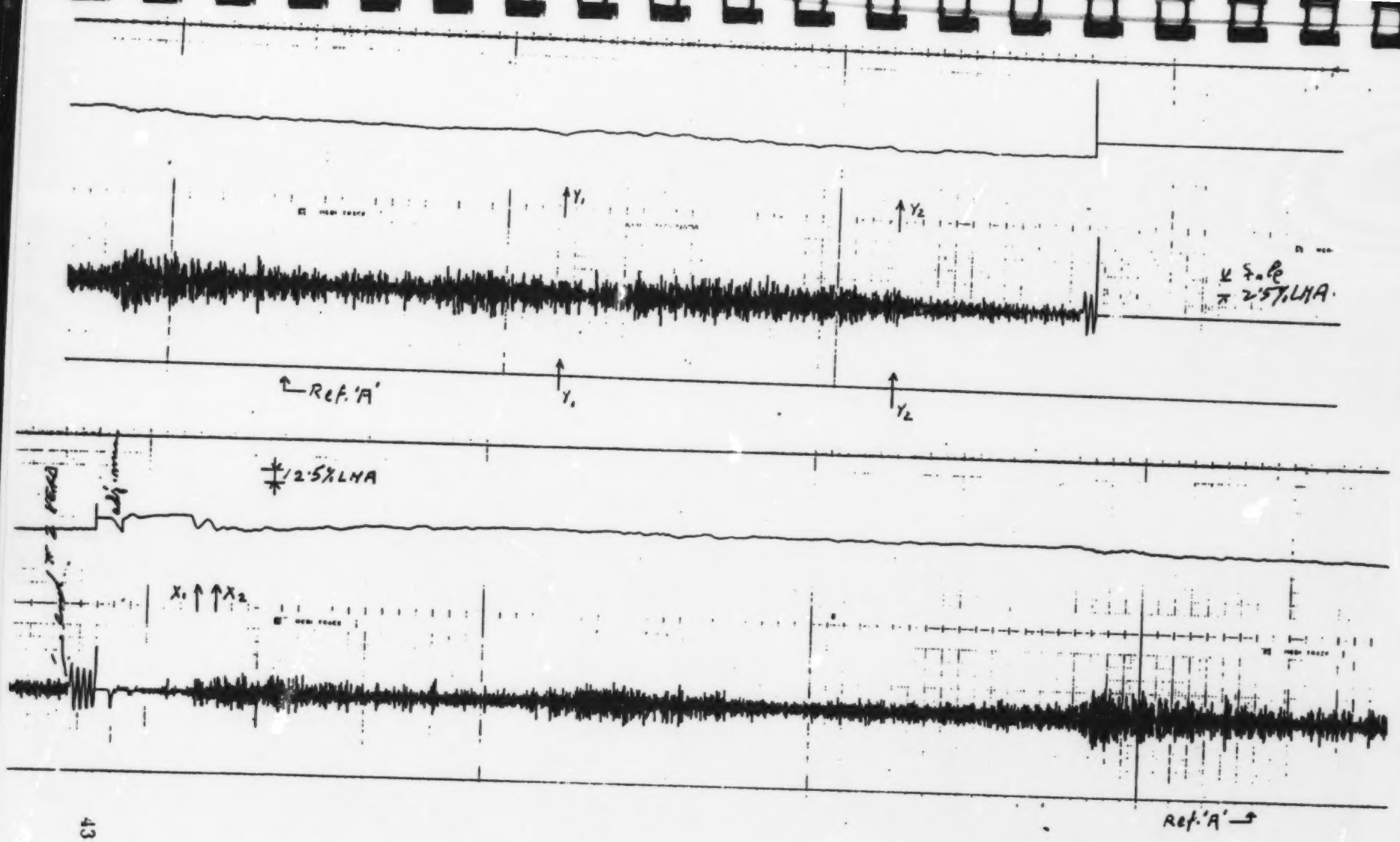


Fig. 11 (continued) — 1989 03 15 LMA-250 test #2 of rope #13; West-skip rope-end with Magnograph's *Gould 222* recorder

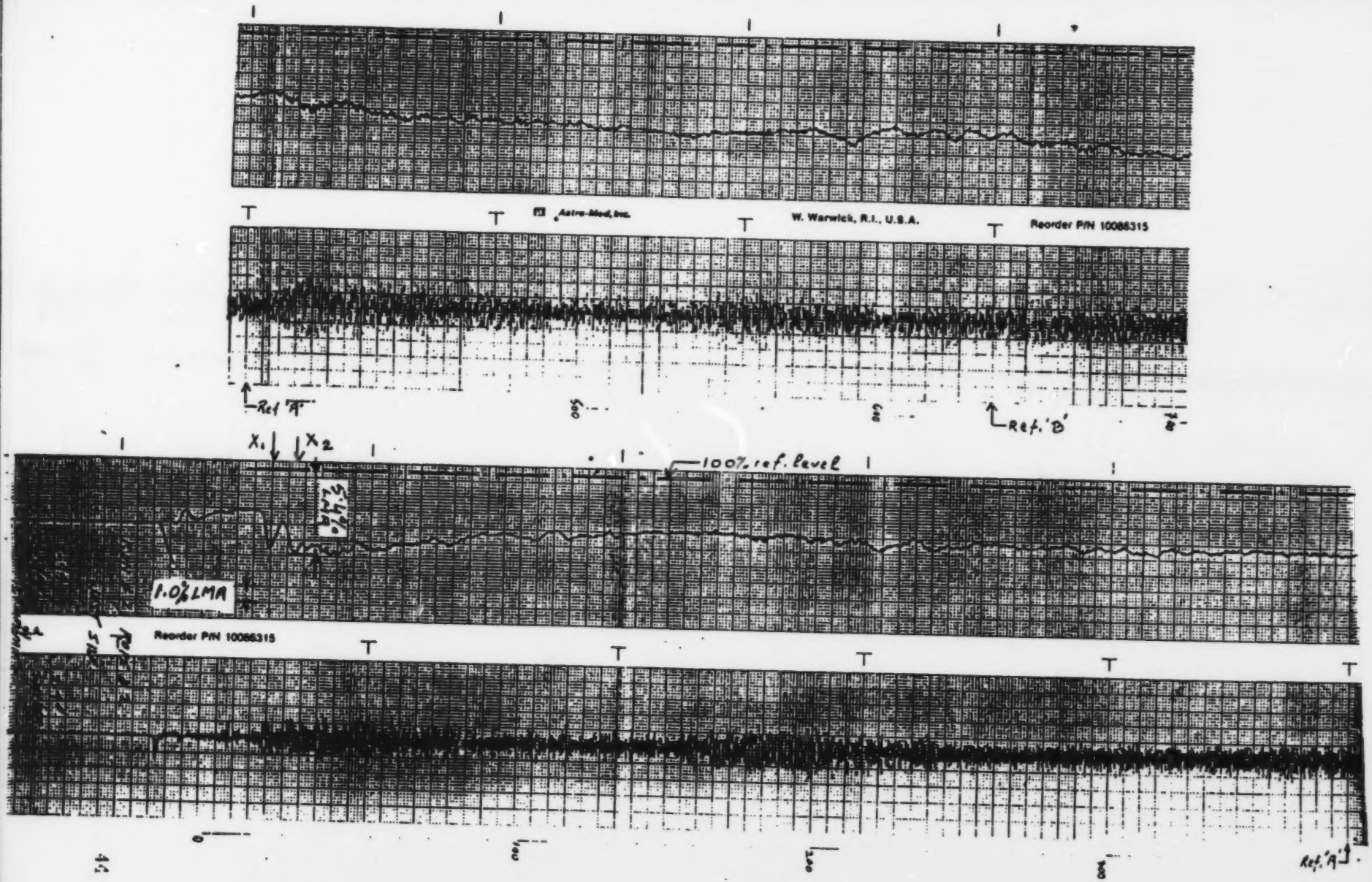


Fig. 12 — 1989 03 15 LMA-250 testing of rope #13; West-skip rope-end = run #2, East-skip rope-end = run #6

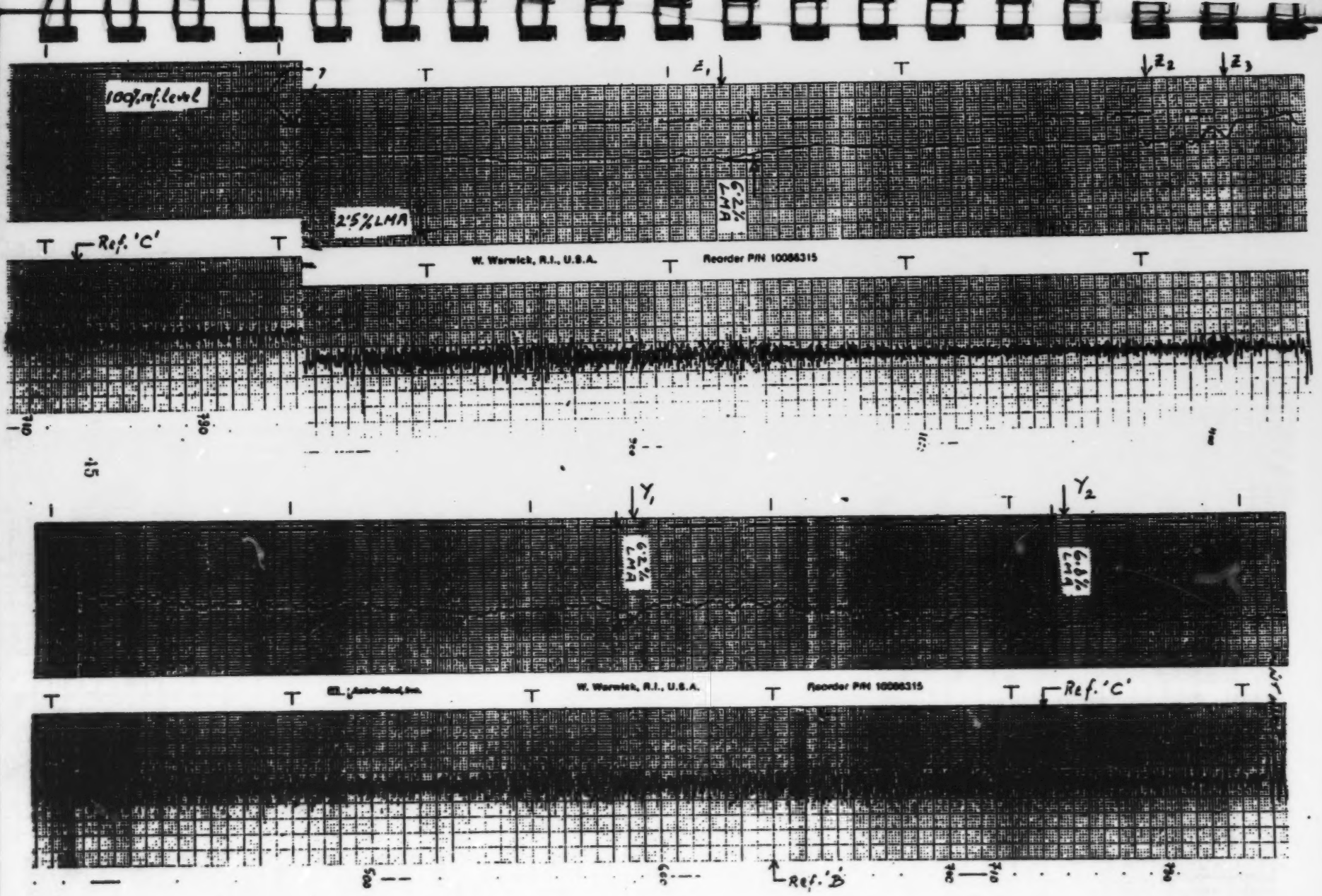


Fig. 12 (continued) — 1989 03 15 LMA-250 testing of rope #13; West-skip rope-end = run #2, East-skip rope-end = run #6

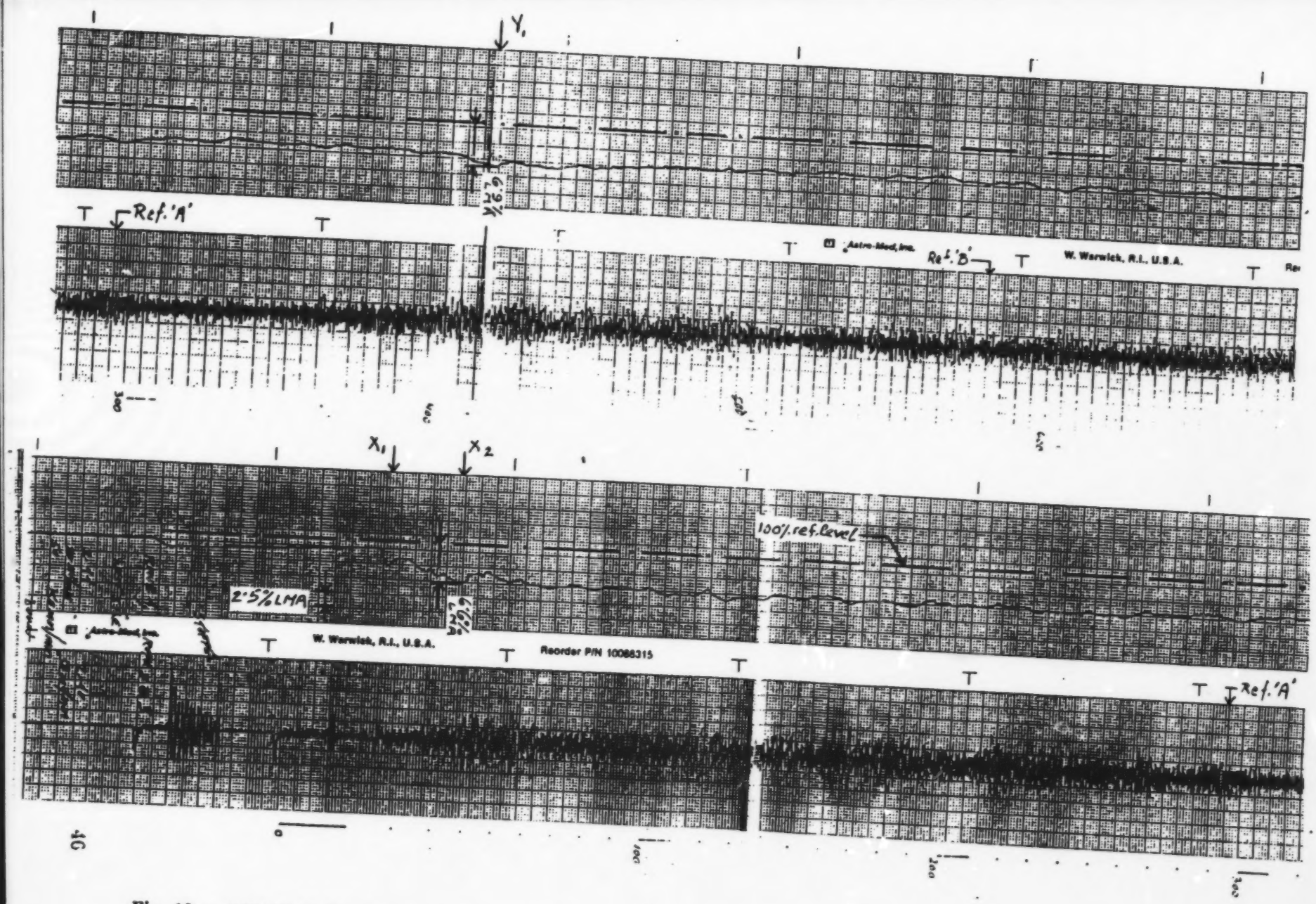


Fig. 13 — 1980 03 15 LMA-250 testing of rope #14; West-skip rope-end = run #4, East-skip rope-end = run #12

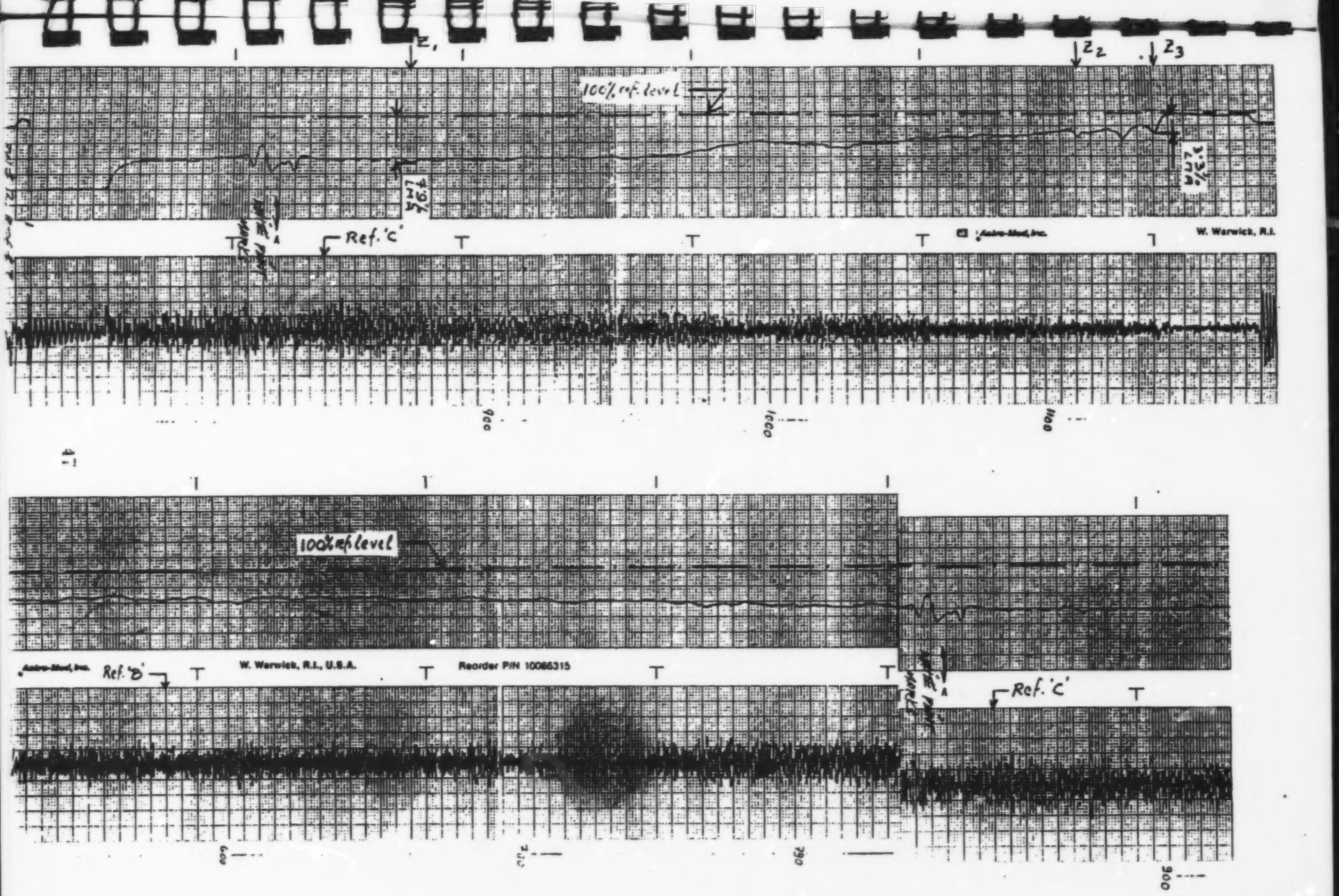


Fig. 13 (continued) — 1989 03 15 LMA-250 testing of rope #14: West-skip rope-end = run #4. East-skip rope-end = run #12

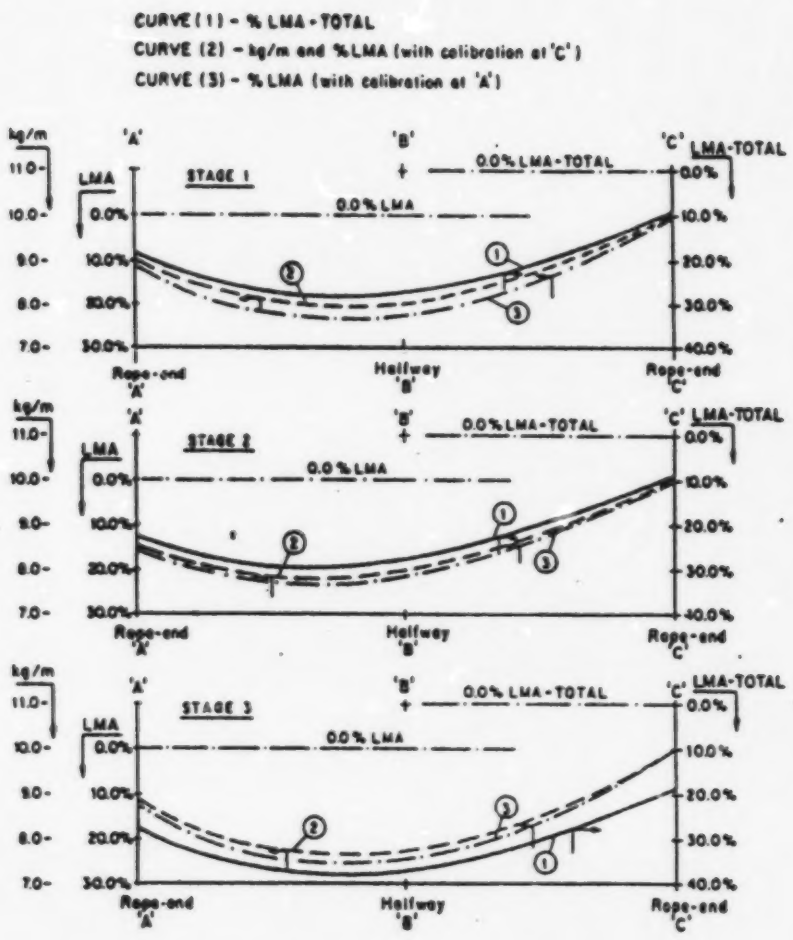


Fig. 14 (after ref. 17) -- Disparate LMA chart-readings, depending on the condition of the rope-calibration-segment

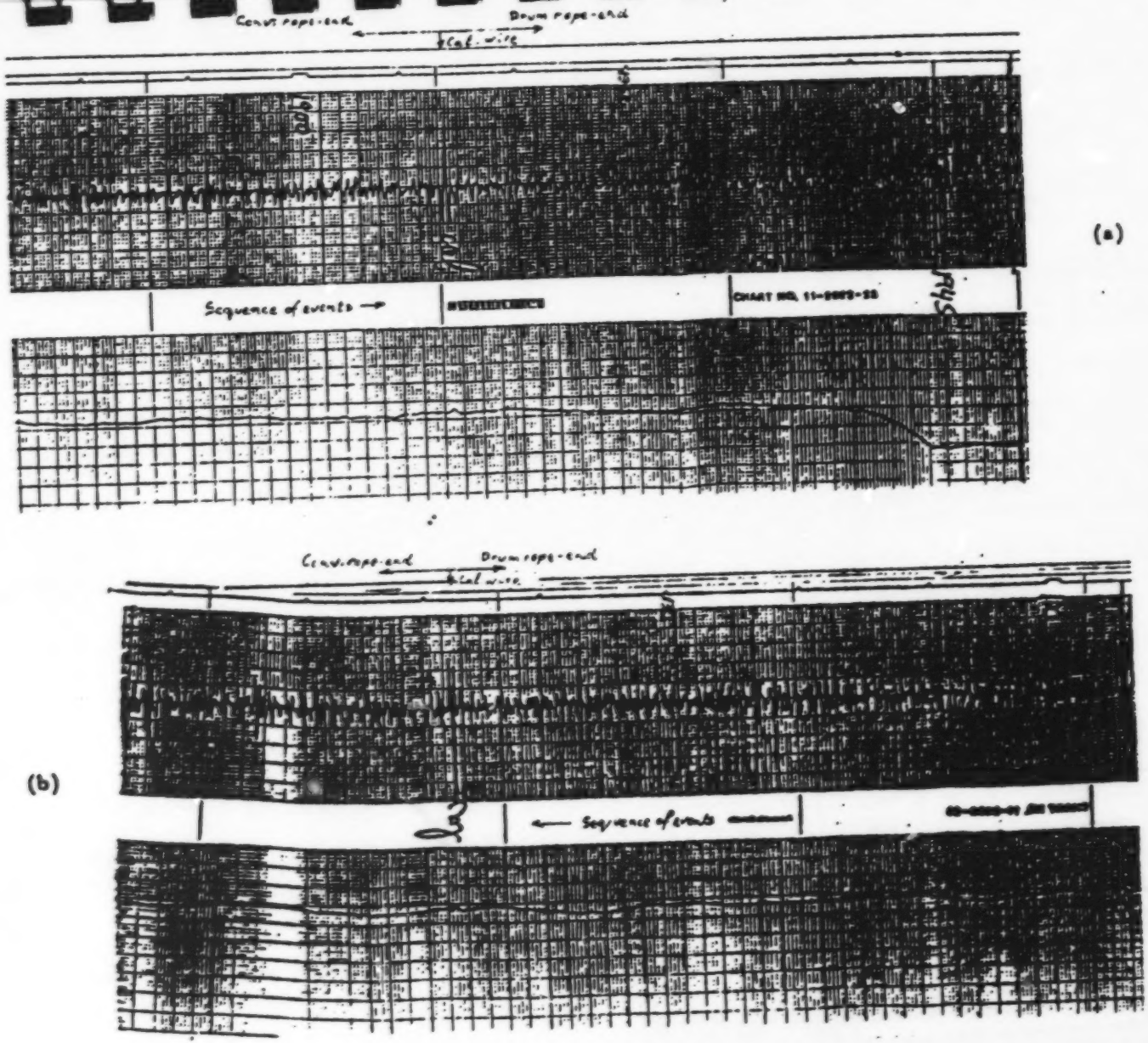


Fig. 15 — Use of 'calibration wire' to assist with the splicing together of two chart-segments (after Fig. 10 of ref. 17);

——— – – – chart-segments: (a) from conveyance to 'marker', and (b) from 'marker' to drum

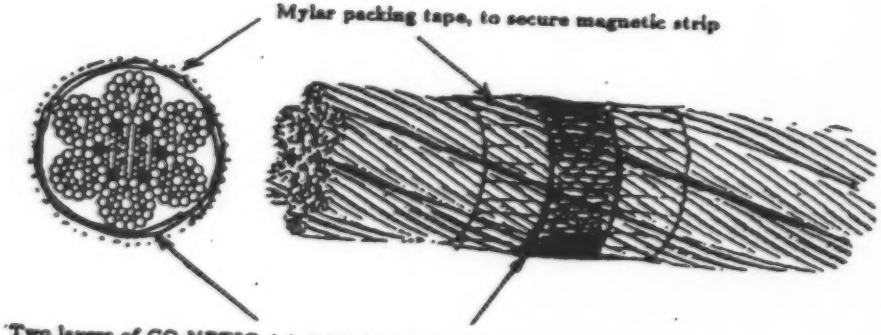


Fig. 16a — Sketch of recommended temporary 'marker' placement process

MAGNETIC SHIELD CORPORATION

PERFECTION MICA COMPANY

740 NORTH THOMAS DRIVE, BENSENVILLE, ILLINOIS 60106 U.S.A.

PHONE: 708/766-7800; TWX: 910-256-4815

CO-NETIC AA Foil
Perfection Annealed

Thickness		Width	
Inches	mm	Inches	mm
.002	0.051	4	101.6
.004	0.102	4	101.6
.004	0.102	15	381.0
.006	0.152	4	101.6
.006	0.152	15	381.0
.010	0.254	4	101.6
.010	0.254	15	381.0

NETIC S3-6 Foil
Perfection Annealed

Thickness		Width	
Inches	mm	Inches	mm
.004	0.102	4	101.6
.004	0.102	15	381.0

Ordering — Specify quantity in linear feet.
CO-NETIC AA Foil
NETIC S3-6 Foil
Thickness width of coil.

Annealing — All foil has been Perfection Annealed for maximum attenuation. No further annealing is required to obtain optimum magnetic shielding properties.

Lengths — Standard coils of 25, 50 and 100 linear feet. Other coil lengths also available. Priced per linear foot.

Shipment — Standard widths shipped immediately from stock.

Backing — All sizes available with double-faced Pressure Sensitive Tape and release coated liner. Temperature range 0°F. to 200°F. (−18°C to 93°C). Specify with P.S.T. backing. Shipment within one week of receipt of order.

Slitting — Foils can be slit to a minimum width of ¼" (6.350mm), with or without backing. Width tolerance ±.010" (0.254mm). Shipment within three weeks of receipt of order.

Thickness — Foil tolerance is ±10% of thickness.

Fig. 16b — Magnetically permeable foil material for temporary 'marker' use

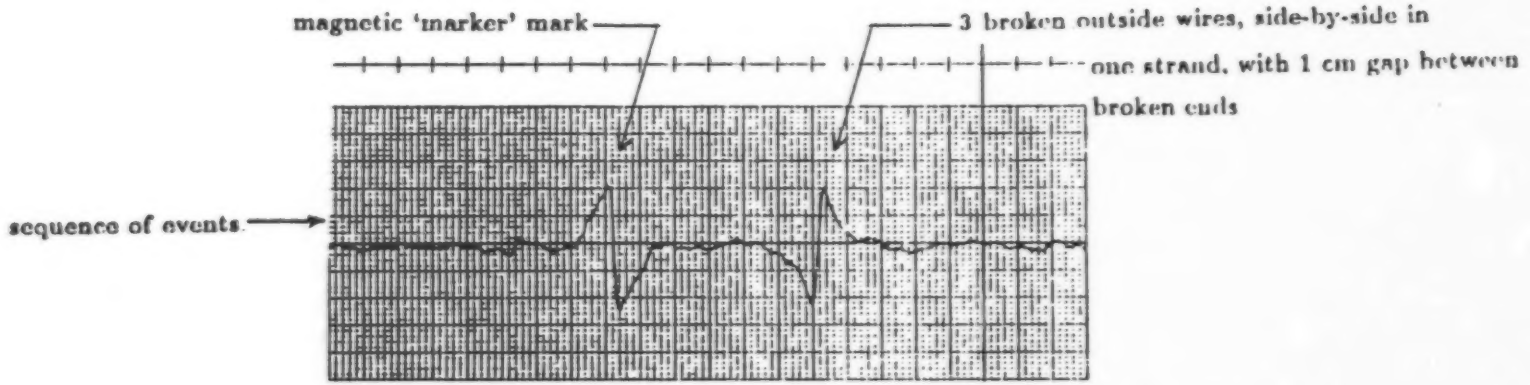

magnetic 'marker' mark
3 broken outside wires, side-by-side in one strand, with 1 cm gap between broken ends
sequence of events

Fig. 17 — Magnograph's LF trace, obtained with a temporary 'marker' and three broken outside wires

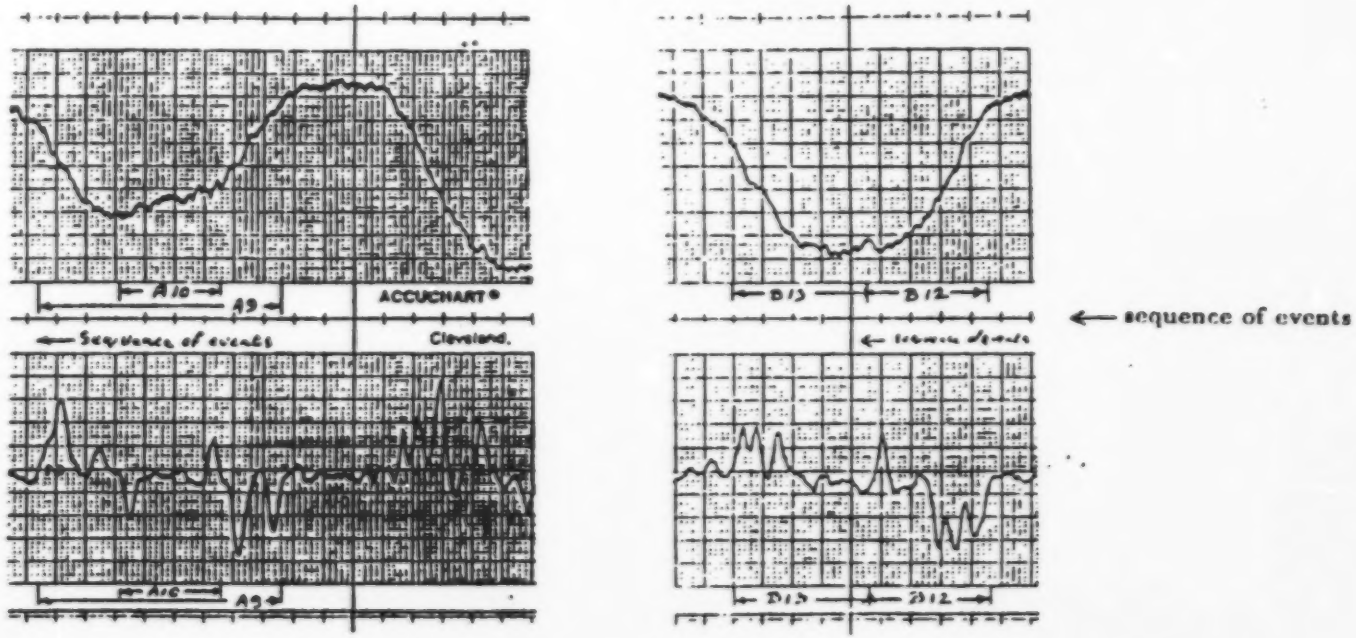


Fig. 18 (after ref. 7) — Magnograph strip-chart of artificial rope-defects (A9+A10) and (B12+B13)